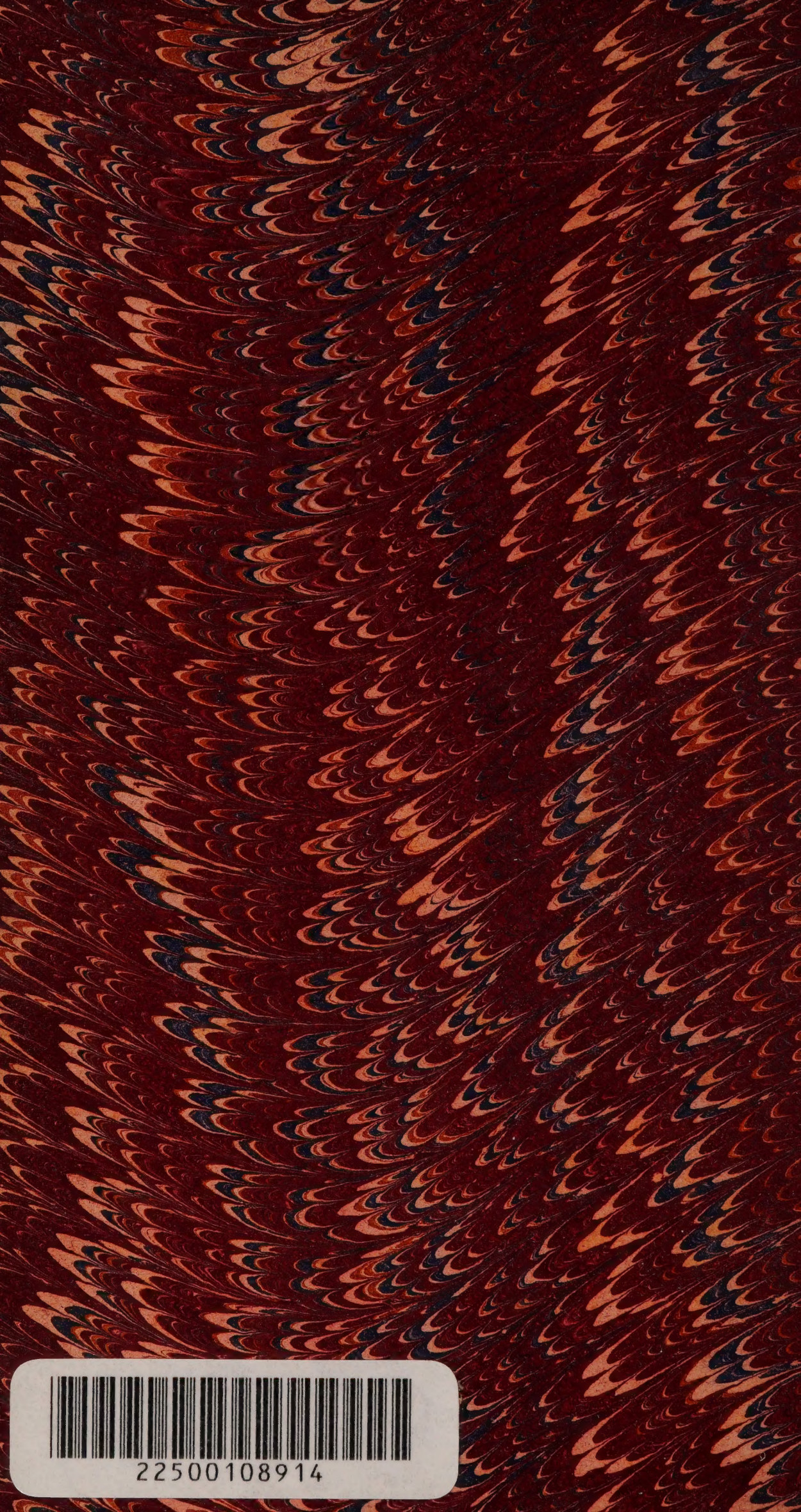
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F. Cumberlege Thompson.

FIFTEENTH ANNUAL REPORT

OF

THE LOCAL GOVERNMENT BOARD,

1885–86.

SUPPLEMENT

CONTAINING THE

REPORT OF THE MEDICAL OFFICER

For 1885.

Presented to both Houses of Parliament by Command of Her Majesty.

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ANNUAL REPORT

OF THE

MEDICAL OFFICER

OF

THE LOCAL GOVERNMENT BOARD

FOR THE YEAR

1885.

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REPORT.

TO THE RIGHT HONOURABLE THE PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

Sir,

The work of your Medical Department during the year 1885 was largely concerned with cholera, and this has recently formed the subject of a special report to your Board. In the present volume I have the honour to present to you an account of other business which engaged the department during the year.

This report has been unavoidably delayed, owing to precedence being demanded by other business: and I have used the delay to bring down to recent date the results of certain scientific work that was in hand during 1885.

References. During the year, in addition to the duties devolving on your Medical Department in respect of cholera, I find that some six or seven thousand matters were referred by the Board and other departments of Government for the consideration and advice of the Department.

Conferences. Many conferences also have been held with representatives of local sanitary authorities:—principally with reference to the medical considerations involved in proposals for local byelaws where the adaptation of sanitary principles to the circumstances of particular localities came into question; and with reference to the medical points to be held in view by authorities proposing to borrow public money for the erection of isolation hospitals or for other objects of local sanitary advantage. This is a branch of departmental duty which, it deserves notice, occupies much time, and is always tending to increase.

I.—Vaccination and Public Vaccination.

Vaccination officers' returns. (1.) Analysis of the returns of vaccination officers in England and Wales made during the year had reference to the children whose births were registered in the year 1883. Of 890,780 such children 9·2 per cent. had died without vaccination, and 85·6 per cent. had been vaccinated at the time the return was made: leaving 5·2 per cent. not known to be dead or vaccinated. The addition to the vaccinated population of the country made by the births registered in 1883 had then been 762,080; the addition presumably made to the non-vaccinated population, 46,745; of which number about a fifth part had one or other reason assigned for the omission, while the other four fifths were "unaccounted for" by the vaccination officers, and represented children removed from one district to another, together with the children of parents who had probably disobeyed the law. In the appended analytical return (A., No. 1) the 5·2 per cent. of children not known to be dead or vaccinated, is examined for the various administrative

MEDICAL OFFICER'S REPORT.

areas of the Kingdom, and the experience of 1883 is compared with that of the five preceding years.

Public vaccination.

(2.) The vaccination provided at the public expense was, during 1885, supervised in the usual manner by inspectors of this Department in the case of 287 unions, comprising 1,433 vaccination districts. In most of these districts the arrangements for public vaccination were found to be working in a quite satisfactory manner, and in 915 of them awards of money were made from the Parliamentary grant to the several vaccination contractors. Particulars of these awards are given in the second of the appended returns (A., No. 2).

Lymph-supply: (*a.*) human.

(3.) The educational stations recognized by the Board, being those from which certificates of proficiency in vaccination are obtainable by medical students and others, as well as the vaccine stations appointed to supply lymph to the National Vaccine Establishment, have continued their operations in customary manner, and from these various stations 9,327 charged tubes and 2,686 charged points were received during the year. All these educating and lymph-supplying stations have been specially supervised by Dr. Stevens on behalf of your Board. Additional supplies to the extent of 11,785 charged tubes were also received by the Establishment from operators in various parts of the country, whose work had been approved by inspectors of the department (Appendix A., No. 3).

(*b.*) animal.

(4.) The Animal Vaccine Station of the Board has also during the year continued its work, and a report of its operations is given by Dr. Cory in an appended paper. (A., No. 4.) At this station 4,054 persons were primarily vaccinated and 2,882 were re-vaccinated, and from it supplies of lymph to the extent of 17,164 ivory points were furnished to the Board's Vaccine Establishment. Dr. Cory records some interesting observations on the "keeping quality" of this animal lymph. As he has previously established an identity between calf lymph and humanized lymph in the degree of their "insertion success" when both are used in a fresh condition, so now he shows (at all events for English practice) that there is much less difference than at one time was believed to exist between the two kinds of lymph in respect of the degree of success obtainable from them after keeping during ordinary periods of time. For this equal result, however, it is requisite that each sort of lymph should be collected on the day which experience shows to be proper for the collection of that lymph.

Alleged injury by vaccination

(5.) Inquiry was made during the year by inspectors of the department into seven instances occurring in the public and private vaccination practice of the Kingdom, where there was allegation of injury to children from the operation. They proved to be of the usual character: the injury, where there was any, having been some kind of inflammation, occasionally erysipelatous, of the child's arm. The experience of the year called for a note,

warning against the use of "vaccination shields," and this note has been largely issued from the National Vaccine Establishment.* MEDICAL OFFICER'S REPORT.

II.—Investigations by Medical Inspectors.

The above-mentioned conferences with local authorities, respecting proposals for byelaws, hospitals, and the like, have sometimes taken place in London, sometimes in the district concerned. In twenty-five instances during 1885, these conferences involved local inquiry by officers of the department.

Other local inquiries by medical inspectors have been called for on account of some serious prevalence of disease or of some serious shortcoming in the performance of sanitary duty by local authorities. These inquiries have been 34 in number and have extended to 23 urban and 24 rural areas; diphtheria being the disease which has most often called for investigation. (Appendix A., No. 5.)

Some more general subjects also have employed the inspectors of the Department.

In the early months of 1885, *typhus fever*, in small and circumscribed outbreaks, was on several occasions heard of by the Board. These occurred for the most part in populous northern towns, and were the occasion of an inspection by Mr. Spear of this Department. One little outbreak occurred also in a metropolitan district. This fever has for some years been among the rarer diseases of England; but we have had uneasy suspicions of its existing here and there, as if waiting its opportunity again to become epidemic. And we know that when once it does gain a foothold in a crowded town, it is capable of very wide, prolonged, and disastrous extension among an indigent population. It is satisfactory, therefore, to note that during the successive quarters of 1885 there has been no evidence of any tendency of the disease to increase; and that the winter of 1885–86 has passed over without any general prevalence of typhus in the United Kingdom. Typhus is a disease which, it should be observed, is more especially controllable by those sanitary authorities that have provided isolation hospitals for their districts. Typhus fever.

On the watch for risks to public water supplies, the Department had occasion in 1885 to investigate the case of districts on the river Ure in Yorkshire, with the more particular object of learning how far the public water services of Ripon and York might be endangered by impurities received by that river. The appended report by Mr. Sweeting (App. A., No. 6) is instructive on the general question of water-supplies drawn from rivers where the Water pollution: Ure inspection.

* "The Medical Officer of the Local Government Board occasionally hears of cases of erysipelas following vaccination and traceable to the use of old and dirty '*vaccination shields.*' If in any case, as where a dress is worn dyed with a possibly irritative dye, a vaccinator thinks some means of 'protection' to a vaccinated arm to be desirable, he had best define the material and the manner of application of such appliance as he judges to be wanted in the particular case; and it appears to the Medical Officer important that every such appliance should be of a kind to be destroyed and replaced whenever it becomes soiled, and particularly that it should not be of a kind likely to be kept for subsequent use. The Medical Officer would, therefore, urge on vaccinators to discourage the use of the so-called '*vaccination shields.*'—October 31st, 1885."

rivers receive sewage and refuse matter from places above water intakes. It shows that under the actual circumstances, present at the time of inquiry, of the river-flow and of the vegetable and animal life in the river, a course of 10 to 15 miles from the nearest considerable sources of pollution had so far sufficed to purify the river at Ripon as to permit it to furnish, with care as to intake and as to filtration, such a water supply to Ripon as chemists found no fault with; and that under the observed circumstances of the river below Ripon, the discharge into the river of the sewage of that city and of Boroughbridge, together with an abundance of town refuse from these and various other places, though forming a large total of impurity brought by the Ure to the Ouse, did not prevent the river Ouse from furnishing the city of York (about 23 miles below Ripon and 15 below Boroughbridge) with a water which, after filtration, had in the estimation of the inhabitants, the qualities of a satisfactory drinking water. The security of the water supplies of the two cities was not however established either by the chemists' analyses or by popular approval. Neither are we in possession of adequate knowledge of the conditions which affect and determine the limits of the "self purifying power" of rivers; and we cannot tell what disaster might arise to towns which take their drinking water from rivers if on occasion those limits should be passed. In the case of the river Ure, much of the impurity that it received was through mere wantonness, as for example the common use of it for the disposal of ashes by the people along its banks; and the most serious source of impurity, from the excrements of populations on the river, might have been largely reduced if the authorities of towns had applied some cleansing process to their sewage before allowing its discharge into the stream. Meanwhile, it behoves such populations as Ripon and York, which derive their drinking water from a river seriously contaminated by agencies beyond their own direct control, to be aware that they are having an experiment performed upon their lives, an experiment contrary to the provisions of English law; and that their own care as to intake arrangements and filtering processes ought hardly to be otherwise regarded than as a condition (doubtless an important condition) of the experiment of which they are the subjects.

Rag flock inquiry.

Dr. Parsons has made inquiries during the year into the sanitary condition of the rag trade, in continuation of those upon which he reported in 1881. His recent investigations (App. A., No. 7) have been into the manufacture of shoddy, rag-flock, and similar substances from woollen and from mixed woollen and cotton rags, and into the influence of such businesses upon health. Like other dusty occupations, they are found provocative of a form of bronchial catarrh, and this affects some classes of workers so generally as to have received the name of "flock fever." And occasionally, small-pox or other infection is conveyed by the rags used in these manufactures, though not so frequently as by the cotton rags used in paper making. None of these diseases were heard of among the general public as resulting from the use of

flock stuffing or other material manufactured from rags. Dr. Parsons describes the expedients adopted in certain factories for reducing the various risks to health incurred by the workers, and concludes his report by indicating the precautions which are generally available for the purpose.

III.—The Connexion of Scarlatina with Disease in Milch Cows.

Scarlatina inquiries.

Previous experiences of milk epidemics

Outbreaks of disease related to local milk-supplies have frequently, since the classical report by Dr. Ballard on Enteric fever in Islington in 1870, been the subject of study by local sanitary inquirers; and in almost every year since the constitution of your Board, your Medical Department has been called on to investigate such occurrences. Sometimes the disease has been enteric fever, sometimes scarlatina, sometimes diphtheria; and within the experience of the Board there have been fifteen instances where one or other of these diseases has been shown upon sufficient evidence to have been distributed with the milk-service of the families invaded. In the case of the outbreaks of scarlatina, it was inevitable that infection of the milk by human agency should present itself as the readiest explanation of the facts; but as successive epidemics have occurred and have been found capable of more exact study, distrust of this explanation has arisen, and the means by which the milk receives infective properties had come to be regarded as unknown.

It was in 1878, in the case of an outbreak of diphtheria in Kilburn and St. John's Wood, that the Department first became seriously impressed with its ignorance of the methods by which milk obtained infective power. In that case, there was no question about the fact of infection having been distributed by milk; the noteworthy circumstance had appeared that consumers of the implicated milk at one place ceased to suffer at the time when another set of consumers of the implicated milk in another place began to suffer; and it was possible to assert, that none of the agencies by which milk, after being taken from the cow, may become infective, could with any shadow of probability have been in operation.

In this case, though no serious illness had occurred among the cows at the time when the milk was acquiring its disease-producing ability, minor ailments of the cows were not excluded, and in the result, the question of "risk from specific fouling of milk by particular cows suffering, whether recognized or not, from specific "disease," was seen to be arising.

An epidemic of scarlatina in St. Giles and St. Pancras in 1882 * was the subject of investigation by Mr. Power for the Board; and the disease was here distributed with a milk-service derived from a Surrey farm. In this case two facts could be affirmed: the one that a cow recently come into milk at this farm had been suffering from some ailment, seemingly from the time of her calving, of which loss of hair in patches was the most con-

* Supplement to Board's Twelfth Annual Report.

spicuous manifestation; the other that there existed no discoverable means by which the milk which had coincided with scarlatina in its distribution, could have received infective quality from the human subject. The circumstances of the milk-service did not, it is true, in this case permit of a relation being demonstrated between ailment of the particular cow and the disease spread from the farm. But the facts were so far suggestive that, at the instance of the Board, some experimental observations were made by Dr. Klein as to the concern of animals with human scarlatina: and it was found that a definite disease was producible in the cow by means of scarlatina-infection, producible most readily when the cow was in milk.

The experiments were not at the time carried further than the production of this disease, and the recognition of certain of its characters; among these the most interesting was its quality of communicability from one animal to another by inoculation.

Hendon scarlatina in 1885.

Three papers in the Appendix to the present report (A., No. 8) have reference to investigations which were directed by the Board, last December, in view of information furnished by Mr. Wynter Blyth, the Medical Officer of Health for Marylebone. This officer had observed a sudden outbreak of scarlatina in his district to be associated with the distribution of milk by a particular retail dealer, and that this dealer obtained the greater portion of his supply from a farm at Hendon. Mr. Blyth had found reason for believing that the disease had prevailed exclusively among customers furnished with milk from that source.

Mr. Power, to whom the Board entrusted the duty of making more extended inquiry into the facts concerning milk-supplies from this Hendon farm, presently learned that a similar prevalence of scarlatina had occurred about the same time in other parishes in and near the metropolis that were furnished with milk from the same farm; and that in those parishes, as in Marylebone, the prevalence of the disease had been very much restricted to consumers of this milk.

I refer to Mr. Power's report (App. A., No. 8*a*) for the steps by which he first established a presumption that the Hendon milk had been the vehicle of scarlatina to its London consumers; by which he afterwards excluded pre-existent human disease at and about the Hendon farm, and excluded also anything of the kind commonly known as "sanitary" conditions there, as having had concern with the infectivity of the milk; and by which he came successively to regard certain sections of the milk-supplies within the farm, and eventually certain cows, as having to do with the observed results. The whole of Mr. Power's report on these matters will have to be studied before the exactness of his observation and the validity of his inferences can be duly apprehended. In the end he has demonstrated, beyond reasonable doubt, the dependence of the milk-scarlatina of December on a diseased condition of certain milch cows at the farm; a condition first introduced there in the previous month by some animals newly arrived from Derbyshire; and he finds strong circumstantial evidence

for believing that the later phenomena of this dependence were brought about through the extension of the diseased condition of one set of animals to another set, after the fashion of an infection. Mr. Power leaves to others to give a full description of the phenomena of the disease observed in the cow. Its manifestations, he tells us, were not particularly conspicuous, and one of the more prominent, namely sores on the udders and teats, was very possibly common to it and to other less important states observed in milch cows.

Its clinical features.

I am enabled, by the favour of the Epidemiological Society, to reproduce, as a second paper (App. A., No. 8*b*), an account of the morbid appearances in the Hendon cow-disease, recently presented to that society by Dr. Cameron, the Medical Officer of Health for the district and the medical adviser of the Hendon farmer. His account consists partly of observations actually made by himself among the cows of the farm, and he brings these down to a later date than the completion of Mr. Power's etiological inquiries. But further, with the aid of people familiar with cows and who thought they recognized in the disease at the farm one stage of a disease which they were able to describe as a whole, Dr. Cameron has drawn up what he and his informants together would regard as a connected clinical history of the disease. I have thought that, provisionally, his paper will have practical value to the milk-farmer.

Pathology of cow illness.

The third report of the series (App. A., No. 8*c*) is by Dr. Klein, whose services were invited by the Board, as soon as circumstantial evidence had established a relation between scarlatina and the consumption of Hendon milk. Dr. Klein records his early investigations into the intimate nature of the ailment present among the cows. In its own province Dr. Klein's report is as important and interesting as Mr. Power's, and its more immediate significance lies in the complete harmony between the conclusions obtained from Mr. Power's etiological researches and the inferences as to communicability and other characters of the Hendon cow-disease that follow from pathological inquiry. By the inoculation into calves, either directly of the discharges from cow-ulcers, or indirectly of subcultures artificially prepared, of the micro-organisms contained in those discharges, Dr. Klein has succeeded in producing, now local, now general, disease in the calf; disease having unmistakeable affinities in its local phenomena with the Hendon cow-disease, in its constitutional manifestations with scarlatina in the human subject:—on the one hand, ulcers on the skin of the calf anatomically identical with the ulcers on the teats of milch cows: on the other hand, general disease in the calf, at first of inconspicuous nature, but passing on to serious changes in the internal organs, more particularly in the liver and kidneys of the calf; the more characteristic of these changes being anatomically identical with those resulting in the human subject from the operation of the scarlatina poison. Dr. Klein's earlier Researches into the Minute Anatomy of Scarlatina will be found in the Report of the Medical Officer for 1876 (New Series, No. VIII.), where they are illustrated by some drawings of microscopical appearances. These had prepared the way for Dr. Klein's observations of the past

Medical Officer's Report.

year, recorded and illustrated in the following pages. They will be found of the deepest concern, alike to the human and the comparative pathologist.

At the present date, a portion of the grant annually made by Parliament for the scientific purposes of the Board is being allotted to further study of the relations that exist between human scarlatina and diseases of animals; and it is necessary that continuous observations should be made by the Department of the conditions under which bovine animals suffer from the Hendon malady, and of the extent to which that malady plays a part in the occurrence of scarlatina in human communities. For I find reason, in our observations of last year, to expect that a measure of additional control may be obtained over a disease which still, in spite of the general sanitary progress of the country, is fatal to some 17,000 to 18,000 persons during the average year in England and Wales.

[While this report is passing through the press, I learn from Dr. Klein that, among other important observations recently made on this matter, he has obtained from the blood of ordinary human scarlatina a micro-organism identical in its morphological characters with that inhabiting the ulcers of the Hendon cow-disease.]

IV.—Small-pox Hospitals in London.

Fulham small-pox hospital.

I have to present in an appended memorandum (A., No. 9), the result of Mr. Power's further observations on the influence of Fulham Hospital upon the neighbourhood surrounding it. This memorandum brings the story of the Hospital and its influence down to the end of the London small-pox epidemic of 1884–85, and it will be found altogether confirmatory of the experiences recorded in Mr. Power's former Reports. Time after time that this hospital has been open, but most at times when small-pox was beginning to assume its epidemic quality, the disease has appeared in excessive amount in houses round the hospital. The excess has always been graduated according to the proximity of the houses to the hospital; it has always been uniform upon the four points of the compass. From the more recent experiences we may learn that improvement in hospital administration—removal of opportunities of personal infection, provision of a carefully watched ambulance service, limitation of number of patients received at one time into the hospital—have been without appreciable effect upon this excess. Now, as before, the "special area" of Mr. Power's reports, that is, within a circle of a mile radius round the hospital (or roughly, an area of three square miles), has suffered from small-pox to more than double the degree that parts beyond the special area have suffered; the houses of the area within half-a-mile of the hospital (roughly, an area of three-quarters of a square mile), having been attacked at three times the rate of the more distant houses of the area, and to nearly four times the rate of the parts beyond it.

Experience since improved management.

Other London experiences.

As the Board are aware, the reason why the influence of Fulham Hospital on its neighbourhood has for the last five years been the subject of anxious study by the Medical Department is

that, in that study, questions affecting in an important degree the public health of the kingdom have been involved. Accordingly, no factor in the problem has escaped attention, and no pains have been spared to come to trustworthy conclusions. With the present resources of the Department it has not been possible to undertake similar personal research into the circumstances of other metropolitan hospitals and their neighbourhoods; and, as you know, the Medical Department has no concern with that section of the Board's business which deals with matters of metropolitan administration.

Nevertheless, we cannot be indifferent to the question whether the intra-urban small-pox hospitals of the metropolis have operated to increase or to decrease the total quantity of small-pox in London,* and I propose on the present occasion to note from such limited material as is at my disposal, how far the recent experience of the metropolis may be in accord with the experience of Chelsea, Fulham, and Kensington.

(*a.*) The Health Officers of Camberwell and of Greenwich, reporting on the year 1884, tell of excessive prevalence of small-pox upon the portions of their districts near to *Deptford* Hospital. (*b.*) The Health Officer for Lambeth, reporting for the same year, records the same thing for *Stockwell* Hospital, 53 out of 138 cases in that large parish at the commencement of the 1884 epidemic having occurred in the houses within a quarter-mile of this hospital. (*c.*) Dr. Tripe, examining the number of cases removed to hospital during certain months of 1884 from various areas around *Homerton* Hospital. represents them as 133, 52, 12, and 4 upon equal populations living within a quarter-mile circle, a more distant quarter-mile zone, a following half-mile zone, and the rest of the parish. (*d.*) Dr. Gwynn shows, for *Hampstead*, that during the 1881 epidemic when the hospital was closed, 0·58 per cent. of houses were attacked in the parish, those within a quarter-mile of the hospital suffering to the extent of 1·5 per cent., whereas in the epidemic of 1884 when the hospital was open, 1·9 per cent. of the total houses of the parish were invaded, those within a quarter-mile of the hospital suffering to the extent of 20·9 per cent. And the Health Officer of St. Pancras has told a like story for the parts of his district adjacent to Hampstead.—Thus much we learn of the London districts that have relation with other small-pox hospitals of the Asylums Board; and similar experiences reach me as to Highgate and West Ham Hospitals, which are situated on the edge of the metropolis, and receive London patients among others.†

Of Deptford.

Of Stockwell.

Of Homerton.

Of Hampstead.

---

* In my report of 1882 upon hospitals, I had occasion to observe that the comparative incidence of small-pox—of London by the side of the provinces, of late years in comparison with former years—had come to be a matter eminently deserving of study in the interests of the metropolis as a whole; and in my evidence before the Commission I gave some material for the commencement of such a study.

† Of the provinces, the department has even less knowledge than of the metropolitan districts here cited. There are but few small-pox hospitals in country towns. Enough facts, however, have been reported of them to make it probable that the London experience is shared by other towns, and is not peculiar to the metropolis.

District incidences.

I would here take leave to point out that the machinery of district registration of deaths is not well adapted to the discovery of the facts concerning the influence of small-pox hospitals in London, principally for the reason that the boundaries of registration districts have no fixed relation to hospital areas. Fulham Hospital, for example, stands at the junction of three districts, together covering some 10 square miles, and the influence of the hospital upon each several district is so far obscured that if the discovery of that influence had been dependent on the examination of the mortality in districts, it would probably have long eluded detection. Thus the principal use of district statistics to the problem in question consists in the evidence they may furnish of *change in the rank* of a district (qua small-pox) after the establishment of a small-pox hospital in or near it, and of change in its rank contemporaneous with the use or disuse of that hospital. The Commissioners of 1881 made use of district death-records in this sense, and showed the deposition of Hampstead from the first rank which it held before it had a hospital, to a comparatively low rank in the list of metropolitan districts after its hospital was at work. And anyone appealing to the reports of the Registrar-General may see how Hampstead regained its position in 1879–83 while the hospital was closed, small-pox still being abundantly present in London, and how it lost its position again in 1884 after the hospital recommenced its operations.* So he may see how Hackney and Camberwell, which for 20 years before 1870 stood among districts of the first rank in regard of their freedom from small-pox, afterwards became debased to a place among the worst. They are shown by the Registrar-General (Annual Summary for 1884) contesting with each other and some eastern parishes which shall show the largest yearly mortality from small-pox. This was after the establishment of Homerton Hospital in Hackney in 1871, and of Stockwell and Deptford Hospitals on either side of Camberwell in 1871 and 1877 respectively.†

Total of metropolitan experience.

The whole of the experiences now on record concerning the districts of London which are in special relations with small-pox hospitals combine, I think, to form a very strong corroboration of the view of the Commission of 1881, that in the metropolis all small-pox hospitals share the disastrous ability of Fulham

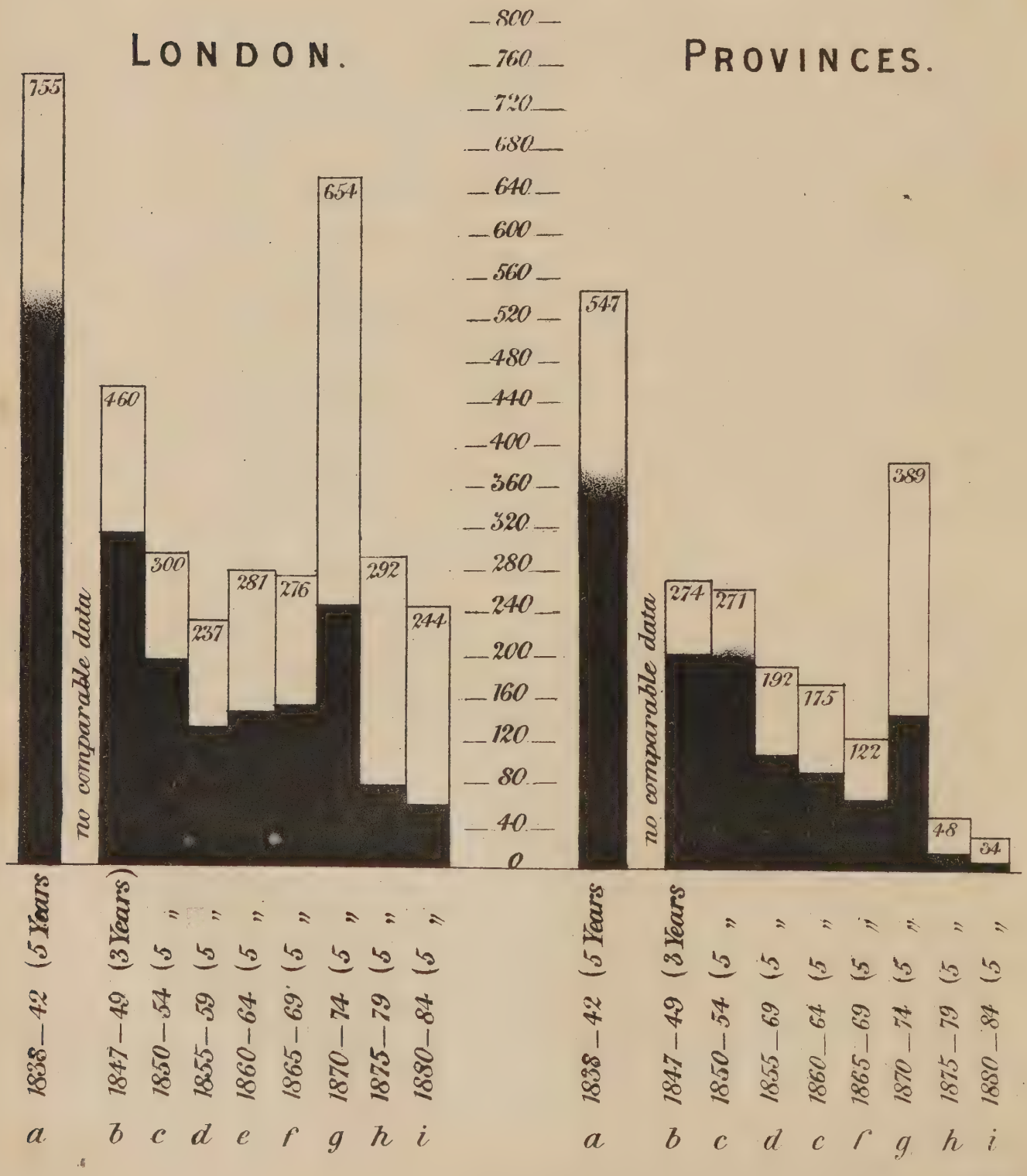
* It is only for people who have not studied Mr. Power's reports that I note as follows :—The opening of a hospital has not been determined by any pre-existing abundance of cases in the particular district or parish containing the hospital. A hospital has been opened or re-opened to meet the wants of London as a whole, or of a large section of London, and the localities contributing the earlier cases have very often been at a considerable distance from the newly-opened hospital.

† The facts as to Greenwich district, containing the Deptford hospital, cannot be readily discerned, owing to combinations and severances of districts during recent years. Lambeth, in which Stockwell hospital is placed, appears by the above-quote summary to hold an intermediate rank on the list of districts suffering from small-pox, and it held some similar rank in former years. The Registrar-General in the above-quoted summary directs attention to the exceptional rank held by Lambeth during 1877–84.

COMPARISON OF LONDON WITH THE PROVINCES.

Diagram showing mean Annual Smallpox rates, per million population at all ages, during successive periods since the commencement of Registration.

The share of Smallpox mortality borne by children under five, in each period, is shown in black.



DANGERFIELD, LITH. 22, BEDFORD ST COVENT GARDEN. 13109. 11/86.

Hospital to spread small-pox "by some means or other" (as the Commission has it) over the neighbourhoods around them. This ability is now, I hold, proved to extend to the distance of at least a mile, and to be independent of lines of human communication. It has now (Reports of 1884–5) been shown to be exerted when the number of acute cases in a hospital has been restricted to 20 or 30, and it was on one occasion exerted when only five acute cases were in hospital together. It has not been extinguished, as Mr. Power's recent researches and the reports of health officers show, by the regulation of methods of transit, or by the removal of opportunities for personal communication with patients in hospital.

Influence on comparative death-rate of metropolis.

It is to this influence of hospitals in maintaining small-pox over large areas of the metropolis that I must needs ascribe a measure of that excess which has recently become conspicuous in the small-pox death-rate of London as compared with that of the provinces. Some such excess has indeed been visible from earlier times, before London was provided with small-pox hospitals, and it was justly ascribed to a greater neglect of vaccination in London. But of recent years a new factor has plainly come into operation. Whereas in five-year periods before the great European epidemic of 1871, the small-pox death-rate of London only once reached the double of the provinces, it has in the last two of such periods been maintained at a point six-fold and seven-fold that which has affected other parts of England; and this has been the case notwithstanding the amendments in London vaccination practice, which have had the effect of reducing, below any former experience, the small-pox mortality of children.—This changed attitude of London towards the provinces in respect of small-pox (see diagram inserted* and figures in footnote), dating from the time when London and not the country became plentifully supplied with hospitals for the disease, deserves especial consideration by any whose first thought is for the aggregate metropolis. For those whose concern is with the particular sections of London, the facts will suffice that the five intra-urban small-pox hospitals in London have excess of small-pox around them; and that in the case of the hospital which has been specially studied, this excess has amounted (during such portions of ten years as have seen the

* This diagram reproduces and brings down to later times the information furnished by myself to the Hospitals Commission of 1881 : for convenience sake the figures of the diagram are here repeated :—

Period.	*a.* 1838-42.	*b.* 1847-49.	*c.* 1850-54.	*d.* 1855-59.	*e.* 1860-64.	*f.* 1865-69.	*g.* 1870-74.	*h.* 1875-79.	*i.* 1880-84.
London - -	755	460	300	237	281	276	654	292	244
Provinces -	547	274	271	192	175	122	389	48	34

Or, if we should represent the rate of London by a constant 100, the

Rate of Provinces would be	72, *a.*	59, *b.*	90, *c.*	81.½ *d.*	62, *e.*	44, *f.*	59, *g.*	16, *h.*	14. *i.*

hospital at work, but not during other portions of the ten years when it was shut) to a three-fold incidence of small-pox upon the three nearest square miles as compared with its incidence on the remainders of circumjacent districts (Mr. Power's Report, Table C.).

In my last annual report I pointed out that, while the view of the Royal Commission that 30 or 40 acute cases of small-pox might safely be treated in hospitals within the metropolis had guided the action of the Metropolitan Asylums Board, that body had not seen their way to acting on the further view of the Commission which attached "paramount importance" to reducing, by means of contrivances which the Commission believed might be devised in the construction of hospitals, "within the smallest "limits the chance of spreading infection." Inasmuch as, on the evidence afforded during 1883–85, it may now be confidently said that the limitation of numbers within the several intra-urban hospitals has not had the result that was hoped for, I submit that the time has now come when the other means recommended by the Commission for "reducing the chance of spreading infection" ought to be tried.

V.—Auxiliary Scientific Investigations.

Streptococcus of foot-and-mouth disease.

The researches of Dr. Klein into the nature of infective processes appear to have demonstrated another member of the class of infective microphytes. The malady known as foot-and-mouth disease (App. B., No. 1), which affects cattle, sheep, pigs, and certain other animals, is highly contagious, but the characters of the contagium had not been made out. It has now been identified by Dr. Klein with a definite kind of micrococcus occurring in wavy chains, streptococcus, in the vesicles of the disease. This can be grown in artificial media, through successive subcultures, and distant generations have, like the contents of the original vesicle, the power of inducing foot-and-mouth disease in animals previously healthy.

Dr. Klein finds this power to be most surely exerted when the animals are *fed* with the infective matter; not so readily when the poison is received by inoculation or through the respiratory tract. In Dr. Klein's hands, however, inoculation of sheep has appeared to have this very notable effect; namely, that though it did itself not produce any conspicuous disturbance of health, yet the animals which had been inoculated became refractory to the influence of the poison subsequently administered to them by feeding. This result cannot yet be certainly affirmed, and further investigation is wanted into a matter of so great pathological interest and such direct importance to the agriculturist.

Tubercle bacilli.

With Mr. Lingard, Dr. Klein has investigated some points in the etiology of tuberculosis (App. B., No. 2)—(1.). It has generally been believed that the bacilli found in the caseating deposits of tubercle are essential elements in the transmission of tubercular

disease from animal to animal. It was desired to put this belief to the test of experiment, but it was found impossible to obtain sections of tubercular deposits from which tubercle bacilli were unquestionably absent. Absent to any microscopic examination they might be; but (especially since we cannot identify them in any spore state) it was felt unsafe to affirm their absence from the actual specimens which did, as a matter of fact, produce disease by their inoculation into animals; and the general belief on the subject could not therefore be either proved or disproved.

Tubercle of fowls.

(2.) Another common belief relates to fowls that seem to get "spontaneously" affected with tubercular disease. It had been supposed that they derived this disease from food contaminated by human tubercular sputa; and in the result it does appear that they can become infected by such feeding. Two interesting points appear during this research: the one, that the tubercle of fowls is of the nature rather of the disease which affects man than of that which prevails in bovine animals; the other an indication that the tubercle derived from the human subject and used to produce disease in fowls may undergo some loss of its infective power during its passage through the fowl.

Chemistry of infection.

Dr. Wooldridge contributes (App. B., No. 3) to this report some observations which may be regarded as tending to cast doubt on a hypothesis frequently held, that the morbific operation of infective microphytes is exerted through the production by them of a poisonous alkaloid (ptomaine) from the blood or tissue of the infected animal, in like manner as septic organisms behave to proteid solutions. He would provisionally bid us regard the operation of pathogenic bacteria as being through the conversion of proteid material and the production of substances, not alkaloidal in character, but analogous rather to peptone and abrin, albuminous matters already known to be capable of injuring the animal that receives them into its circulation.

Disinfection by perchloride of mercury.

Drs. Klein and Cash, working upon lines originally indicated by Dr. Koch of Berlin in 1881, have conducted some very notable investigations into the influence of perchloride of mercury upon bacteria, and as to the characters and meaning of this influence. Dr. Klein (App. B., No. 4), distinguishing throughout the power of an agent to *kill* bacteria from its power to *restrain* their growth, and experimenting on the action of this perchloride upon a variety of bacteria, under various conditions of their life, arrives at the conclusion that the antiseptic or restraining powers of this salt as well as its disinfecting or killing powers, are considerably greater than those of any other known substance; but that these powers differ widely according to the species, phase of growth, even according to the pedigree of the different organisms investigated. It has been found that non-pathogenic organisms offer the greatest resistance to the operation of the mercuric salt, a result conforming with previous experience of other "disinfecting" agents. In the course of his very interesting paper he describes

the precise measures by which it is practicable to produce (after the fashion of Pasteur) a modified form of anthrax in sheep, by inoculating the animals with the material of anthrax along with corrosive sublimate; and he tells how these means can easily be carried out in practice without the special aid of experts. I need not comment on the practical importance of this incidental observation of Dr. Klein's.

Protection by it.

Dr. Cash's observations during the year (App. B., No. 5) confirm the view he had previously entertained respecting the ability of mercuric salts (among which he continues to prefer the perchloride) administered to an animal, to protect against death from anthrax subsequently inoculated into the animal. The drug would appear to operate in much the same way as a previous attack might have operated, to give, for a time at least, a feebler quality to an attack of the disease, and this in its turn appeared to produce immunity against subsequent attack. The researches of Drs. Klein and Cash are clearly gaining for us material for a better understanding of the nature of infective processes.

Natural history of b. anthracis;

Mr. Laws has experimented (B., No. 6) during the year upon bacillus anthracis grown in vacuo, and has found its form and growth to be modified in some respects; but both in this subject and in some further observations upon the thermal death-point of the same bacillus, Mr. Laws' experiments had to be left incomplete. Dr. Cash (B., No. 7), examining the influence of oxygen and ozone on bacillus anthracis, has found that no superabundance of oxygen injures the growth of the bacilli or lowers their power of killing animals; rather he tells us, it facilitates their multiplication. But ozone used in sufficient quantity appeared so to alter the morbific properties of these bacilli, that animals inoculated with them died after a longer interval than the control animals of the experiment; and this alteration appeared to be produced before the point was reached at which the ozonised sub-culture became acid. Upon the spores of anthrax bacillus no influence seemed producible by ozone.—Dr. Cash has also examined the influence of

and of tubercle bacilli.

ozone upon human and bovine tubercle bacilli, and finds some similar influence to be exerted upon these; a certain retardation of their ability to kill rodents being commonly (but not invariably) witnessed.—Perhaps the most instructive point yet reached in the observations of those who have investigated the influence of ozone upon bacteria is, that the presence of this substance has seemed more antagonistic to putrefactive bacilli than to the bacilli of disease.

Bacterial life in water.

Dr. Dupré (B., No. 7) has continued his important investigations into the consumption by bacteria of oxygen from the dissolved air of water. These investigations have been carried on in the face of great experimental difficulties. With all the care that Dr. Dupré could use in the conduct of his inquiries, he has found himself perforce dealing with a mixture of various organisms which he could not identify, and which for practical purposes he has to differentiate into those which are, and those which are not

destroyed by a prolonged heating to a temperature of 60° C. (140° Fahr.). Experimenting with London waters, he obtained by his processes some very notable results, not all intelligible, and pointing conclusively to the hazard of too rapid generalisations about bacterial life. Of special interest to the Board in these results (supposing them to bear further repetition) are the following: (1) Differences are observed at different periods of the year in the behaviour towards oxygen of the bacteria of the water furnished by a London company deriving its supply from the Thames; differences which seem to require for their explanation that there is variation in the power of different bacteria (present at one and another time) to resist a temperature of 60° C., or else that there are seasonal fluctuations in the power of the surviving bacteria to use the oxygen of water-dissolved air; differences which, it is to be observed, would not be in any way discerned by ordinary chemical methods. (2) The faculty of consuming oxygen after resisting a temperature of 60° C. possessed by waters taken from the Thames and Lea, and attributed to the bacteria contained in them, is present in a higher degree in deep-well waters; their special faculty again varying at one and another time, as in the case of the Thames water. If this latter phenomenon should prove to be confirmed by further investigation, we shall be confronted afresh with the possibility of the deep-well water having contained unrecognised spores of bacteria, and also with the question of the influence of light upon bacterial life, for this influence must obviously be exerted in differing measure upon the bacteria in deep wells and in rivers. Meanwhile Dr. Dupré's observations on these deep-well waters illustrate how greatly we need research into the ways of harmless bacteria, as well as into the habits of those which produce disease.

Need for further study of bacterial life.

For, looking at the prodigious part that bacterial life plays in the economy of nature, it is hardly too much to expect that morbific bacteria may come hereafter to be known, not merely as producing disease under certain conditions, but as having, under other conditions, many other functions in that economy. When such bacteria are so circumstanced that they can produce disease, the best thing we can now do may be to poison or boil them; but while provisionally we use such resources, science may expect hereafter to see beyond them. The larger aim of sanitary science, in relation to each harmful bacterium, will be to turn against it such forces of nature as are customarily antagonistic to it. The termination of a case of infectious disease by recovery of the individual, the end of an epidemic in the community, the limitation of area over which infection spreads, of the length of stream along which it can be carried, all point to the existence of such forces. It has long appeared to pathologists that, among agencies antagonistic to the bacteria of disease, none will be found to equal in potency the agency of other bacteria; that probably the "self-purifying" power of our rivers, for example, is the power of some stronger septic bacterium to destroy the weaker and more

mischievous bacteria which are discharged by sewers into our rivers. So that if, among bacteria, as among higher creatures, natural hostilities of that sort result in the destruction or repression, supersession or assimilation, of the weaker by the stronger organism, the study of such hostilities is the study to which we may most hopefully appeal for resources against the forms of bacterial life which we now only know as agencies of disease.

At present we know too little of the natural history of this class of organisms. We recognise among them differences of form; differences in the mode of their growth, in the mode of their reproduction; differences, as we believe, in the degree of their dependence upon air, and in their resistance to one and another degree of heat, in their effect upon this or that chemical substance and *vice versâ*. But we know very little more than this, and practically nothing of the means by which any bacterium exerts its influence in the production of a chemical change or of a disease.

Yet if we are to understand the part that bacteria play in the production of disease, and if, in our endeavours to prevent and modify bacterial disease, we may hope for the aid of other bacteria and of like beings, we require extended and exact knowledge of their life history, of their characters, qualities and habits, of their abilities, affinities and antagonisms; and this knowledge we need, not alone for those which under some circumstances of their existence may be competent to produce disease, but also in respect of those which are harmless, and which may, if rightly utilised, be of avail to us in repressing disease.

I trust that it may be possible, during the present year, to include with our further inquiries into the pathology of scarlatina and into other matters of immediate urgency, some more general researches into this important subject of the life-history of bacterial organisms.

I have the honcur to be,
Sir,
Your obedient servant,

August 1886. GEORGE BUCHANAN.

[Memorandum.—*I am requested by the President to insert in the present volume* (*see page* 217) *observations by Dr. Bridges on that portion of my Report which deals with Small-pox Hospitals in London.*—G. B.]

APPENDICES.

APPENDICES.

APPENDIX A.

App. A. No. 1.
Digest of Vaccination Officers' Returns.

No. 1.

DIGEST of the VACCINATION OFFICERS' RETURNS, with regard to CHILDREN whose BIRTHS were registered in the Year 1883.

The following is the twelfth annual return under the Vaccination Act, 1871. Of 890,780 births returned to the Board by the several Vaccination Officers in England and Wales as registered during the year 1883, the number which at the time the return was made had been registered as successfully vaccinated was 762,080 (being 85·6 per cent. of the whole), and the number registered as having died before they could be vaccinated was 81,955 (or 9·2 per cent. of the whole). Of the remaining 46,745 children, 1,102 (or 0·1 per cent. of the whole) had been registered as insusceptible of vaccination; 93 (or 0·01 per cent.) as having contracted small-pox before they could be vaccinated; 8,110 (or 0·91 per cent.) as having their vaccination postponed by medical certificate; leaving 37,440 (or 4·2 per cent.) as "removed," "not to be traced," or otherwise unaccounted for. If from the 890,780 births returned by these Officers, deduction of the deaths without vaccination be first made, it appears that of the surviving 808,825 children, there were registered at the time of the return 94·2 per cent. as successfully vaccinated; 0·15 per cent. as either insusceptible of vaccination, or as having had small-pox; and 1·0 per cent. as under medical certificate of postponement; leaving 4·6 per cent. as at that time still unaccounted for as regards vaccination.

The proportion of cases unaccounted for in the metropolitan returns for 1883 is 6·5 per cent.; in the provincial returns, 4·9. Of the registered births of the twelve years 1872–83, the proportion not finally accounted for in regard to vaccination in each year respectively has been as follows:—

	Metropolis.	Rest of England.
1872	8·8	4·5
1873	8·7	4·2
1874	8·8	4·1
1875	9·3	3·8
1876	6·5	4·0

	Metropolis.	Rest of England.
1877	7·1	4·1
1878	7·1	4·3
1879	7·8	4·5
1880	7·0	4·5
1881	5·7	4·3
1882	6·6	4·5
1883	6·5	4·9

	Metropolis.	Rest of England.
Average of 5 years 1873–77	8·1	4·1
„ „ 1878–82	6·8	4·4

In 1883, the proportion of cases unaccounted for, after deduction of the postponed cases, in the metropolis and in the rest of the kingdom, was 5·8 and 3·9 per cent. respectively.

For purposes of comparison an addition has been made to the table, showing the total number of cases unaccounted for in each union during the previous five years, with the proportion which such cases bear to the entire number of births registered.

Returns, 1883.

	Returns, 1883.								*Children remaining "unaccounted for" when the Returns for the several Years were received.*	
	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, unvaccinated.	Vaccination postponed.	Remaining.	Per-centage of Children not finally accounted for, including Cases postponed.	*Total Number for the Years 1878-82.*	*Average Per-centage for the Years 1878-82.*
ENGLAND & WALES -	890,780	762,080	1,012	93	81,955	8,110	37,440	5·1	*212,299*	*4·8*
Ditto, excluding Metropolitan Unions.	756,236	648,768	777	81	69,838	7,148	29,624	4·9	*167,083*	*4·4*
METROPOLITAN UNIONS	134,544	113,312	325	12	12,117	962	7,816	6·5	*45,216*	*6·8*
COUNTIES.										
Bedford - - -	5,028	4,296	6	—	517	61	148	4·2	*783*	*3·2*
Berks - - -	7,727	6,894	12	—	535	112	174	3·7	*1,309*	*3·4*
Bucks - - -	4,975	4,410	4	—	429	49	83	2·7	*622*	*2·5*
Cambridge - - -	5,778	5,122	9	—	496	51	100	2·6	*761*	*2·6*
Chester - - -	20,162	17,665	20	—	1,857	159	461	3·1	*2,952*	*2·9*
Cornwall - - -	9,307	8,080	3	1	954	105	164	2·9	*1,359*	*2·9*
Cumberland - -	8,812	7,708	4	—	730	124	246	4·2	*1,436*	*3·3*
Derby - - -	13,577	11,215	6	—	1,409	129	818	7·0	*3,470*	*5·0*
Devon - - -	17,658	15,628	26	—	1,409	164	431	3·4	*2,899*	*3·2*
Dorset - - -	5,306	4,722	1	—	376	66	141	3·9	*887*	*3·2*
Durham - - -	35,935	30,471	42	4	3,478	280	1,660	5·4	*9,316*	*5·4*
Essex - - -	20,341	17,415	23	2	1,544	264	1,093	6·7	*4,408*	*4·8*
Gloucester - - -	16,210	14,089	15	—	1,384	108	614	4·5	*3,496*	*4·2*
Hereford - - -	3,126	2,757	6	—	253	49	61	3·5	*773*	*4·3*
Herts - - -	7,367	6,580	7	—	575	55	150	2·8	*699*	*1·9*
Huntingdon - -	1,519	1,383	—	—	112	6	18	1·6	*165*	*2·1*
Kent (extra-metropolitan)	23,031	20,368	27	—	1,778	193	665	3·7	*3,538*	*3·1*
Lancaster - - -	129,085	109,626	127	—	12,927	1,379	5,026	5·0	*30,331*	*4·7*
Leicester - - -	11,852	7,813	16	50	1,404	54	2,515	21·7	*7,060*	*12·0*
Lincoln - - -	14,567	12,300	10	—	1,368	253	636	6·1	*4,201*	*5·6*
Middlesex (ex.-metropol.)	13,148	10,987	50	—	1,036	151	924	8·2	*3,007*	*5·3*
Monmouth - -	8,501	7,510	7	—	745	44	195	2·8	*1,255*	*3·1*
Norfolk - - -	13,764	11,891	16	—	1,318	158	381	3·9	*1,973*	*2·9*
Northampton - -	9,408	8,102	8	—	804	95	399	5·3	*2,339*	*5·0*
Northumberland - -	15,434	13,411	12	2	1,590	179	240	2·7	*2,634*	*3·4*
Nottingham - -	17,417	14,384	26	—	1,893	194	1,010	6·4	*4,333*	*5·5*
Oxford - - -	5,569	4,817	7	—	480	83	182	4·8	*1,421*	*5·0*
Rutland - - -	724	645	—	—	60	4	15	2·6	*127*	*3·6*
Salop - - -	7,497	6,660	3	—	612	54	168	3·0	*1,143*	*3·9*
Somerset - - -	14,610	12,889	14	—	1,210	159	338	3·4	*2,314*	*3·1*
Southampton - -	18,335	16,248	25	—	1,308	213	541	4·1	*3,280*	*3·7*
Stafford - - -	33,324	28,848	17	14	3,440	121	884	3·0	*5,630*	*3·4*
Suffolk - - -	11,393	9,985	7	—	947	122	332	4·0	*1,783*	*3·1*
Surrey (extra-metropol.) -	14,635	12,777	17	—	1,105	180	556	5·0	*3,192*	*4·6*
Sussex - - -	15,024	13,062	16	—	1,177	186	583	5·1	*3,346*	*4·5*
Warwick - - -	25,080	21,794	22	2	2,396	146	720	3·5	*5,384*	*4·2*
Westmoreland - -	2,007	1,826	3	—	157	11	10	1·0	*135*	*1·4*
Wilts - - -	7,527	6,735	4	—	551	114	123	3·1	*933*	*2·4*
Worcester - - -	18,904	16,718	13	2	1,772	66	333	2·1	*3,518*	*3·7*
York, East Riding -	12,521	10,341	19	—	1,274	99	788	7·1	*3,575*	*5·7*
York, North Riding -	11,897	10,341	15	2	1,061	134	788	4·0	*2,162*	*3·7*
York, West Riding -	73,801	61,377	92	2	7,261	586	4,483	6·9	*25,753*	*6·7*
WALES.										
Anglesey - - -	888	793	—	—	71	5	19	2·7	*156*	*3·2*
Brecknock - - -	1,651	1,422	—	—	179	24	26	3·0	*281*	*3·3*
Cardigan - - -	1,864	1,670	—	—	143	16	35	2·7	*365*	*3·5*
Carmarthen - -	4,122	3,707	—	—	337	29	49	1·9	*316*	*1·5*
Carnarvon - - -	3,528	3,089	5	—	325	33	76	3·1	*491*	*2·6*
Denbigh - - -	2,614	2,310	—	—	240	19	45	2·4	*345*	*2·5*
Flint - - -	2,572	2,292	—	—	208	24	48	2·8	*404*	*2·9*
Glamorgan - - -	20,003	17,446	12	—	1,933	174	438	3·1	*3,370*	*3·6*
Merioneth - - -	1,987	1,718	1	—	201	39	28	3·4	*367*	*3·4*
Montgomery - -	2,074	1,821	—	—	171	31	51	4·0	*641*	*5·7*
Pembroke - - -	2,538	2,161	2	—	251	77	47	4·9	*535*	*4·1*
Radnor - - -	512	449	—	—	47	7	9	3·1	*110*	*3·9*

METROPOLITAN UNIONS.	Returns, 1883.								*Children remaining "unaccounted for" when the Returns for the several Years were received.*	
	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, unvaccinated.	Vaccination postponed.	Remaining.	Per-centage of Children not finally accounted for, including Cases postponed.	*Total Number for the Years 1878-82.*	*Average Per-centage for the Years 1878-82.*
Bethnal Green - -	5,344	4,488	2	1	526	10	317	6·1	*1,786*	*6·9*
Camberwell - -	6,968	5,909	31	—	585	52	391	6·4	*2,395*	*7·3*
Chelsea - - -	3,306	2,797	7	—	330	20	152	5·2	*988*	*6·3*
Fulham - - -	5,047	4,343	11	—	503	23	167	3·8	*1,173*	*5·5*
George, St., Hanover Sq. -	3,667	3,229	10	—	316	16	96	3·1	*1,140*	*5·8*
George, St., in the East -	1,919	1,618	5	—	206	5	85	4·7	*661*	*6·9*
Giles, St., and St. George -	1,468	1,161	1	—	138	7	161	11·4	*881*	*11·3*
Greenwich - - -	5,083	4,092	16	2	455	16	502	10·2	*1,518*	*6·5*
Hackney - - -	6,534	5,534	21	1	572	19	387	6·2	*1,859*	*5·9*
Hampstead - - -	1,305	1,141	9	—	88	6	61	5·1	*224*	*4·1*
Holborn - - -	5,489	4,479	13	—	530	14	453	8·5	*1,909*	*6·8*
Islington - - -	9,950	8,192	25	5	890	194	644	8·4	*4,295*	*8·6*
Kensington - - -	4,229	3,654	14	—	365	21	175	4·6	*1,044*	*4·6*
Lambeth - - -	9,286	7,581	43	—	874	52	736	8·5	*4,772*	*10·5*
Lewisham - - -	2,356	2,043	5	—	194	32	82	4·8	*347*	*3·2*
London, City of - -	967	858	6	—	80	—	23	2·4	*289*	*5·0*
Marylebone - - -	4,953	4,145	14	—	520	42	232	5·5	*1,800*	*7·2*
Mile End Old Town -	4,240	3,444	8	—	371	14	403	9·8	*1,615*	*7·7*
Olave, St. - - -	5,275	4,304	6	—	438	103	424	10·0	*1,257*	*4·7*
Paddington - - -	2,873	2,381	7	—	231	16	238	8·8	*1,128*	*7·9*
Pancras, St. - -	7,764	6,788	15	—	653	55	253	4·0	*2,801*	*7·0*
Poplar - - -	6,442	5,663	10	2	535	16	216	3·6	*1,257*	*4·0*
Saviour, St. - - -	7,577	6,299	6	—	821	60	391	6·0	*2,457*	*6·6*
Shoreditch - - -	5,137	4,302	—	—	428	16	391	7·6	*3,042*	*11·9*
Stepney - - -	2,158	1,890	7	—	210	1	50	2·3	*750*	*6·7*
Strand - - -	774	631	3	—	81	9	50	7·6	*343*	*7·8*
Wandsworth and Clapham	8,121	6,699	19	1	670	105	627	9·0	*2,005*	*5·6*
Westminster - -	1,100	927	1	—	105	23	44	6·1	*317*	*5·1*
Whitechapel - -	2,479	2,231	3	—	206	—	39	1·6	*468*	*3·5*
Woolwich - - -	2,733	2,489	7	—	196	15	26	1·5	*695*	*5·0*
	134,544	113,312	325	12	12,117	962	7,816	6·5	*45,246*	*6·8*

—	Returns, 1883.								*Children remaining "unaccounted for" when the Returns for the several Years were received.*	
	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, unvaccinated.	Vaccination postponed.	Remaining.	Per-centage of Children not finally accounted for, including Cases postponed.	*Total Number for the Years 1873-82.*	*Average Per-centage for the Years 1873-82.*
BEDFORD.										
Ampthill	509	455	—	—	46	1	7	1·6	*42*	*1·6*
Bedford	1,273	1,079	—	—	123	17	54	5·6	*200*	*3·2*
Biggleswade	877	796	2	—	68	6	5	1·2	*66*	*1·5*
Leighton Buzzard	594	529	—	—	50	—	15	2·5	*105*	*3·4*
Luton	1,499	1,199	4	—	198	34	64	6·5	*339*	*5·0*
Woburn	276	238	—	—	32	3	3	2·2	*31*	*2·1*
BERKS.										
Abingdon	654	583	—	—	56	—	15	2·3	*78*	*2·3*
Bradfield	572	517	—	—	47	3	5	1·4	*45*	*1·6*
Cookham	546	488	—	—	40	9	9	3·3	*86*	*3·4*
Easthampstead	376	321	—	—	29	5	11	4·4	*31*	*1·8*
Faringdon	397	366	1	—	20	3	7	2·5	*53*	*2·5*
Hungerford	491	452	—	—	35	3	1	0·8	*38*	*1·4*
Newbury	587	511	5	—	44	14	13	4·6	*207*	*6·6*
Reading	1,548	1,357	4	—	111	47	29	4·9	*236*	*3·1*
Wallingford	408	381	—	—	19	5	3	2·0	*53*	*2·5*
Wantage	535	491	2	—	34	4	4	1·5	*54*	*2·0*
Windsor	981	862	—	—	52	11	56	6·8	*260*	*5·6*
Wokingham	642	565	—	—	48	8	21	4·5	*168*	*5·2*
BUCKS.										
Amersham	585	532	—	—	47	1	5	1·0	*43*	*1·4*
Aylesbury	775	647	—	—	69	32	27	7·6	*198*	*5·1*
Buckingham	551	305	—	—	33	3	10	3·7	*59*	*3·3*
Eton	797	732	—	—	54	3	8	1·4	*52*	*1·3*
Newport Pagnell	840	759	3	—	65	1	12	1·5	*93*	*2·3*
Winslow	221	204	—	—	15	—	2	0·9	*18*	*1·5*
Wycombe	1,406	1,231	1	—	146	9	19	2·0	*159*	*2·2*
CAMBRIDGE.										
Cambridge	1,044	913	4	—	89	9	29	3·6	*136*	*2·7*
Caxton and Arrington	335	314	—	—	20	—	1	0·3	*23*	*1·4*
Chesterton	893	800	—	—	67	4	22	2·9	*126*	*2·8*
Ely	648	553	1	—	74	6	14	3·1	*155*	*4·9*
Linton	418	364	—	—	40	9	5	3·3	*72*	*3·7*
Newmarket	863	780	—	—	73	9	1	1·2	*35*	*0·8*
North Witchford	478	419	3	—	43	4	9	2·7	*50*	*1·2*
Whittlesey	172	160	—	—	11	1	—	0·6	*27*	*2·7*
Wisbech	927	819	1	—	79	9	19	3·0	*157*	*3·3*
CHESHIRE.										
Altrincham	1,681	1,501	—	—	127	22	31	3·2	*233*	*2·6*
Birkenhead	3,865	3,422	3	—	364	8	68	2·0	*338*	*1·8*
Chester	1,502	1,335	1	—	121	11	34	3·0	*130*	*1·7*
Congleton	1,170	1,040	—	—	111	8	11	1·6	*139*	*2·2*
Macclesfield	1,810	1,580	1	—	189	20	20	2·2	*355*	*3·7*
Nantwich	2,135	1,760	2	—	238	52	83	6·3	*631*	*6·0*
Northwich	1,665	1,544	2	—	110	1	8	0·5	*78*	*0·9*
Runcorn	1,242	1,130	1	—	100	3	8	0·9	*65*	*1·0*
Stockport	3,940	3,315	9	—	423	26	167	5·0	*851*	*4·2*
Tarvin	304	283	—	—	15	1	5	2·0	*29*	*1·8*
Wirral	848	755	1	—	59	7	26	3·9	*123*	*2·9*

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CORNWALL.										
Austell, St.	934	836	—	—	80	10	8	1·9	*98*	*2·0*
Bodmin	524	478	—	—	44	—	2	0·4	*32*	*1·2*
Camelford	185	166	—	—	17	—	2	1·0	*23*	*1·9*
Columb, St., Major	463	424	—	—	32	3	4	1·5	*27*	*1·1*
Falmouth	606	513	—	—	69	5	19	4·0	*109*	*3·2*
Germans, St.	485	452	—	—	28	2	3	1·0	*29*	*1·2*
Helston	654	561	—	—	71	10	12	3·4	*164*	*4·7*
Launceston	473	426	—	—	39	1	7	1·6	*35*	*1·5*
Liskeard	814	711	1	—	67	12	23	4·3	*128*	*3·0*
Penzance	1,442	1,248	1	—	164	7	22	2·0	*190*	*2·5*
Redruth	1,507	1,238	1	—	215	20	33	3·5	*248*	*3·6*
Stratton	212	190	—	—	19	—	3	1·4	*28*	*2·3*
Truro	1,008	837	—	1	109	35	26	6·0	*248*	*5·1*
CUMBERLAND.										
Alston-with-Garrigill	103	95	—	—	6	2	—	2·0	*8*	*1·3*
Bootle	509	455	1	—	34	3	16	3·7	*56*	*2·4*
Brampton	278	247	—	—	21	5	5	3·6	*36*	*2·4*
Carlisle	1,719	1,513	—	—	140	28	38	3·8	*221*	*2·5*
Cockermouth	2,270	1,947	2	—	214	53	54	4·7	*510*	*4·9*
Longtown	201	190	—	—	10	1	—	0·5	*15*	*1·3*
Penrith	669	607	1	—	53	1	7	1·2	*43*	*1·2*
Whitehaven	2,371	2,034	—	—	200	22	115	5·8	*465*	*4·0*
Wigton	692	620	—	—	52	9	11	2·9	*82*	*2·3*
DERBY.										
Ashbourne	585	514	—	—	50	5	16	3·6	*127*	*4·2*
Bakewell	893	781	—	—	83	6	23	3·2	*185*	*4·0*
Belper	1,972	1,781	—	—	169	1	21	1·1	*187*	*1·8*
Chapel-en-le-Frith	611	534	1	—	56	5	15	3·3	*133*	*4·3*
Chesterfield	3,757	3,243	3	—	386	20	105	3·3	*689*	*3·4*
Derby	2,934	2,005	—	—	375	70	484	18·9	*1,554*	*10·7*
Glossop	773	632	1	—	85	9	46	7·1	*182*	*4·8*
Hayfield	371	325	—	—	28	3	15	4·9	*69*	*3·4*
Shardlow	1,681	1,400	1	—	177	10	93	6·1	*344*	*4·3*
DEVON.										
Axminster	498	446	—	—	30	5	17	4·4	*76*	*2·9*
Barnstaple	1,024	928	—	—	75	13	8	2·0	*135*	*2·5*
Bideford	541	490	—	—	40	8	3	2·0	*41*	*1·4*
Crediton	476	429	—	—	32	4	11	3·2	*46*	*1·7*
East Stonehouse	535	446	—	—	65	7	17	4·5	*133*	*4·4*
Exeter	1,095	894	1	—	135	21	44	5·9	*241*	*4·2*
Holsworthy	271	247	—	—	21	1	2	1·1	*41*	*2·9*
Honiton	648	590	—	—	39	9	10	2·9	*71*	*2·1*
Kingsbridge	503	463	—	—	32	4	4	1·6	*39*	*1·4*
Newton Abbot	2,022	1,860	3	—	133	8	18	1·3	*159*	*1·5*
Okehampton	462	399	—	—	47	10	6	3·5	*75*	*3·0*
Plymouth	2,365	1,998	5	—	227	24	111	5·7	*746*	*6·3*
Plympton St. Mary	640	562	3	—	48	15	12	4·2	*171*	*5·0*
Southmolton	473	425	4	—	37	4	3	1·5	*42*	*1·7*
Stoke Damerel	1,555	1,334	6	—	120	3	92	6·1	*351*	*4·6*
Tavistock	826	754	—	—	66	—	6	0·7	*32*	*0·8*
Thomas, St.	1,392	1,232	3	—	106	16	35	3·7	*244*	*3·5*
Tiverton	806	738	1	—	48	4	15	2·4	*125*	*3·0*
Torrington	398	366	—	—	23	3	6	2·3	*58*	*2·7*
Totnes	1,128	1,027	—	—	85	5	11	1·4	*73*	*1·3*

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DORSET.										
Beaminster	312	278	—	—	26	4	4	2·6	*49*	*2·9*
Blandford	333	273	—	—	18	17	25	12·6	*131*	*7·0*
Bridport	428	374	—	—	37	9	8	4·0	*59*	*2·6*
Cerne	170	152	—	—	16	1	1	1·2	*22*	*2·3*
Dorchester	532	484	—	—	37	6	5	2·1	*33*	*1·2*
Poole	631	566	1	—	37	2	25	4·3	*92*	*2·9*
Shaftesbury	341	301	—	—	23	7	10	5·0	*88*	*4·7*
Sherborne	355	326	—	—	23	—	6	1·7	*38*	*2·1*
Sturminster	304	280	—	—	21	—	3	1·0	*22*	*1·5*
Wareham and Purbeck	508	470	—	—	29	2	7	1·8	*51*	*2·0*
Weymouth	878	760	—	—	76	15	27	4·8	*206*	*4·7*
Wimborne and Cranborne	514	458	—	—	33	3	20	4·5	*96*	*3·7*
DURHAM.										
Auckland	3,482	2,919	1	—	423	21	118	4·0	*705*	*4·2*
Chester-le-Street	1,698	1,444	3	—	185	18	48	3·9	*199*	*2·3*
Darlington	1,591	1,388	—	—	137	7	59	4·2	*473*	*5·6*
Durham	2,452	2,101	7	2	240	10	92	4·1	*555*	*4·5*
Easington	1,656	1,371	—	—	47	19	219	15·0	*461*	*5·2*
Gateshead	4,455	3,763	4	2	469	37	180	4·9	*1,615*	*7·6*
Hartlepool	2,240	1,896	—	—	246	32	66	4·4	*305*	*3·1*
Houghton-le-Spring	1,442	1,263	1	—	142	6	30	2·5	*214*	*3·1*
Lanchester	2,350	2,081	3	—	209	4	53	2·4	*274*	*2·4*
Sedgefield	682	578	—	—	74	6	24	4·4	*156*	*4·7*
South Shields	4,538	3,587	6	—	492	57	396	10·0	*1,818*	*8·6*
Stockton	2,140	1,787	1	—	182	11	159	7·9	*857*	*8·5*
Sunderland	6,106	5,334	15	—	526	38	193	3·8	*1,483*	*5·4*
Teesdale	575	507	1	—	50	6	11	3·0	*114*	*3·6*
Weardale	528	452	—	—	56	8	12	3·8	*87*	*3·0*
ESSEX.										
Billericay	484	426	1	—	35	3	19	4·5	*75*	*2·9*
Braintree	813	739	1	—	60	2	11	1·6	*145*	*3·7*
Chelmsford	982	890	1	—	67	6	18	2·4	*92*	*1·8*
Colchester	930	797	1	—	65	19	48	7·2	*200*	*4·4*
Dunmow	515	468	—	—	35	8	4	2·3	*38*	*1·5*
Epping	687	618	1	—	46	6	16	3·2	*89*	*2·9*
Halstead	477	438	—	—	30	6	3	1·9	*61*	*2·6*
Lexden and Winstree	656	599	—	—	54	—	3	0·5	*36*	*1·0*
Maldon	699	621	1	—	51	4	22	3·7	*128*	*3·4*
Ongar	292	255	1	—	19	4	13	5·8	*64*	*4·2*
Orsett	694	612	4	—	61	5	12	2·4	*63*	*2·2*
Rochford	794	689	3	—	64	8	30	4·8	*119*	*2·9*
Romford	1,411	1,227	1	—	117	14	52	4·7	*300*	*4·6*
Saffron Walden	577	543	1	—	20	2	11	2·3	*70*	*2·5*
Tendring	1,077	979	1	—	72	5	20	2·3	*98*	*2·0*
West Ham	9,253	7,514	6	2	748	172	811	10·6	*2,812*	*7·4*
GLOUCESTER.										
Barton Regis	5,543	4,925	9	—	450	21	138	2·9	*914*	*3·2*
Bristol	1,787	1,508	2	—	181	4	92	5·4	*533*	*5·7*
Cheltenham	1,429	1,120	2	—	141	20	146	11·6	*815*	*11·6*
Chipping Sodbury	532	469	—	—	38	10	15	4·7	*89*	*3·4*
Cirencester	601	529	—	—	38	8	26	5·7	*120*	*4·0*
Dursley	370	326	—	—	27	7	10	4·6	*64*	*3·6*
Gloucester	1,537	1,285	2	—	154	12	84	6·2	*276*	*3·6*
Newent	324	291	—	—	26	2	5	2·2	*30*	*1·9*
Northleach	249	225	—	1	18	—	6	2·4	*51*	*3·7*

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GLOUCESTER—*cont.*										
Stow-on-the-Wold	252	227	—	—	11	6	8	5·6	*66*	*4·9*
Stroud	1,209	1,081	—	—	109	6	13	1·6	*98*	*1·6*
Tetbury	145	130	—	—	8	1	6	4·8	*37*	*4·2*
Tewkesbury	368	324	—	—	29	2	13	4·3	*62*	*3·2*
Thornbury	588	536	—	—	37	3	12	2·6	*48*	*1·8*
Westbury-on-Severn	815	702	—	—	76	5	32	4·5	*240*	*5·7*
Wheatenhurst	187	167	—	—	16	1	3	2·1	*7*	*0·7*
Winchcomb	274	244	—	—	25	—	5	1·8	*46*	*3·3*
HEREFORD.										
Bromyard	292	257	—	—	25	3	7	3·4	*90*	*5·6*
Dore	220	198	—	—	9	5	8	5·9	*54*	*4·5*
Hereford	950	835	1	—	77	21	16	3·9	*200*	*4·0*
Kington	325	296	—	—	25	—	4	1·2	*73*	*4·1*
Ledbury	311	271	—	—	31	3	6	2·9	*75*	*4·5*
Leominster	380	325	1	—	30	14	10	6·3	*136*	*6·7*
Ross	440	394	3	—	36	2	5	1·6	*101*	*4·1*
Weobley	208	181	1	—	20	1	5	2·9	*44*	*3·8*
HERTS.										
Albans, St.	871	769	2	—	70	6	24	3·4	*76*	*2·0*
Barnet	1,132	991	1	—	87	15	38	4·7	*132*	*2·8*
Berkhampstead	505	438	—	—	52	4	11	2·9	*62*	*2·5*
Bishop's Stortford	617	572	1	—	36	2	6	1·3	*56*	*1·7*
Buntingford	176	159	—	—	12	1	4	2·8	*18*	*2·1*
Hatfield	206	180	—	—	22	2	2	1·9	*27*	*2·6*
Hemel Hempstead	476	415	—	—	45	1	15	3·4	*58*	*2·5*
Hertford	465	431	—	—	31	2	1	0·6	*52*	*2·2*
Hitchin	873	779	2	—	83	3	6	1·0	*37*	*0·8*
Royston	508	466	—	—	35	4	3	1·4	*29*	*1·0*
Ware	536	478	—	—	37	7	14	3·9	*59*	*2·1*
Watford	936	842	1	—	61	7	25	3·4	*86*	*1·9*
Welwyn	66	60	—	—	4	1	1	3·0	*7*	*1·7*
HUNTINGDON.										
Huntingdon	576	530	—	—	40	2	4	1·0	*56*	*1·9*
Ives, St.	439	404	—	—	31	1	3	0·9	*46*	*1·9*
Neots, St.	504	449	—	—	41	3	11	2·8	*63*	*2·5*
KENT (Extra-Metropolitan).										
Ashford, East	426	391	—	—	31	2	2	0·9	*41*	*1·8*
Ashford, West	564	512	—	—	36	1	15	2·8	*73*	*2·5*
Blean	588	537	—	—	38	3	10	2·2	*48*	*1·6*
Bridge	398	359	—	—	31	—	8	2·0	*50*	*2·7*
Bromley	1,685	1,446	3	—	172	30	34	3·8	*214*	*2·9*
Canterbury	508	453	—	—	44	—	11	2·2	*86*	*3·3*
Cranbrook	395	365	—	—	22	1	7	2·0	*46*	*2·3*
Dartford	1,798	1,591	1	—	125	10	71	4·5	*273*	*3·2*
Dover	1,184	974	—	—	98	21	91	9·5	*676*	*11·5*
Eastry	867	790	1	—	53	4	19	2·7	*142*	*3·6*
Elham	1,065	942	3	—	72	13	35	4·5	*167*	*3·1*
Faversham	931	862	—	—	63	—	6	0·6	*40*	*0·9*
Gravesend and Milton	714	631	2	—	43	—	38	5·3	*115*	*3·4*
Hollingbourn	398	343	—	—	39	1	15	4·0	*65*	*3·0*
Hoo	140	118	2	—	10	5	5	7·1	*30*	*4·6*
Maidstone	1,496	1,229	—	—	163	11	93	7·0	*335*	*4·5*

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KENT (EXTRA-METROPOLITAN)—*cont.*										
Malling	908	820	3	—	62	5	18	2·5	*97*	*2·1*
Medway	2,192	1,945	3	—	188	12	44	2·6	*141*	*1·4*
Milton	876	790	2	—	60	10	14	2·7	*91*	*2·0*
North Aylesford	1,072	950	3	—	96	5	18	2·1	*74*	*1·6*
Romney Marsh	194	185	—	—	8	—	1	0·5	*8*	*0·8*
Sevenoaks	780	702	—	—	47	8	23	4·0	*115*	*2·8*
Sheppey	576	513	—	—	36	14	13	4·7	*107*	*3·5*
Tenterden	312	284	—	—	21	1	6	2·2	*29*	*1·7*
Thanet, Isle of	1,456	1,324	3	—	114	4	11	1·0	*158*	*2·2*
Tonbridge	1,508	1,312	1	—	106	32	57	5·9	*317*	*4·1*
LANCASTER.										
Ashton-under-Lyne	5,253	4,549	5	—	529	16	154	3·2	*1,064*	*3·9*
Barrow-in-Furness	2,132	1,902	—	—	171	2	57	2·8	*344*	*3·6*
Barton-upon-Irwell	2,397	2,061	1	—	203	23	109	5·5	*583*	*4·8*
Blackburn	6,886	6,084	2	—	647	34	119	2·2	*490*	*1·5*
Bolton	6,927	6,217	6	—	620	3	81	1·2	*330*	*0·9*
Burnley	4,889	4,091	1	—	564	25	208	4·8	*851*	*3·8*
Bury	4,314	3,816	1	—	430	9	58	1·6	*466*	*2·1*
Chorley	1,762	1,537	2	—	175	—	48	2·7	*372*	*4·2*
Chorlton	9,110	7,597	11	—	892	89	521	6·7	*3,807*	*8·2*
Clitheroe	712	623	1	—	65	4	19	3·2	*109*	*3·0*
Fylde, The	1,402	1,215	—	—	140	10	37	3·4	*238*	*3·5*
Garstang	363	341	—	—	16	2	4	1·7	*67*	*3·5*
Haslingden	3,224	2,858	1	—	306	12	47	1·8	*199*	*1·2*
Lancaster	1,412	1,206	—	—	144	26	36	4·4	*268*	*3·9*
Leigh	2,174	1,933	4	—	190	8	39	2·2	*229*	*2·1*
Liverpool	6,290	5,287	5	—	757	4	237	3·8	*1,560*	*4·3*
Lunesdale	213	194	—	—	17	2	—	0·9	*14*	*1·4*
Manchester	5,313	4,544	4	—	562	35	168	3·8	*1,897*	*6·6*
Oldham	6,209	4,506	13	—	726	208	756	15·5	*2,988*	*10·0*
Ormskirk	2,529	2,224	3	—	217	21	64	3·4	*431*	*3·2*
Prescot	4,727	4,003	1	—	537	50	136	3·9	*1,310*	*5·5*
Preston	4,701	3,838	3	—	557	103	200	6·4	*1,304*	*5·6*
Prestwich	4,525	3,865	2	—	396	28	234	5·8	*1,000*	*7·1*
Rochdale	3,466	2,985	11	—	334	35	101	3·9	*715*	*3·7*
Salford	7,043	5,809	8	—	785	109	332	6·3	*2,012*	*5·5*
Todmorden	1,019	892	2	—	85	—	40	3·9	*154*	*2·9*
Toxteth Park	4,638	3,765	22	—	455	100	296	8·5	*1,558*	*7·0*
Ulverston	1,614	1,445	—	—	114	36	19	3·4	*250*	*3·2*
Warrington	2,976	2,369	7	—	359	114	127	8·1	*943*	*6·8*
West Derby	14,783	12,502	7	—	1,329	233	712	6·4	*3,571*	*5·3*
Wigan	6,082	5,368	4	—	605	38	67	1·7	*607*	*2·0*
LEICESTER.										
Ashby-de-la-Zouch	1,150	991	—	50	60	2	47	4·3	*267*	*4·4*
Barrow-on-Soar	1,064	730	1	—	144	7	182	16·8	*689*	*13·1*
Billesdon	303	240	—	—	32	1	30	10·2	*124*	*8·7*
Blaby	889	705	1	—	98	22	63	9·6	*243*	*6·1*
Hinckley	671	586	1	—	77	—	7	1·0	*38*	*1·2*
Leicester	4,819	1,967	8	—	735	6	2,103	43·8	*5,262*	*22·0*
Loughborough	1,007	858	—	—	101	3	45	4·7	*117*	*2·4*
Lutterworth	349	315	3	—	27	1	3	1·1	*32*	*1·8*
Market Bosworth	505	458	1	—	38	3	5	1·6	*71*	*2·7*
Market Harborough	482	432	—	—	38	3	9	2·5	*68*	*2·8*
Melton Mowbray	613	531	1	—	54	6	21	4·4	*149*	*4·5*

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LINCOLN.										
Boston	1,194	971	3	—	133	15	72	7·3	*450*	*7·6*
Bourn	540	473	1	—	48	7	11	3·3	*119*	*4·1*
Caistor	2,303	1,922	2	—	231	69	79	6·4	*545*	*4·6*
Gainsborough	1,102	840	1	—	140	35	86	11·0	*497*	*9·7*
Glandford Brigg	1,432	1,252	—	—	142	4	34	2·7	*233*	*3·4*
Grantham	1,072	957	1	—	78	8	28	3·4	*205*	*3·7*
Holbeach	581	505	—	—	47	6	23	5·0	*163*	*5·1*
Horncastle	607	555	—	—	38	4	10	2·3	*78*	*2·4*
Lincoln	2,159	1,688	2	—	217	73	179	11·7	*1,153*	*1·1*
Louth	886	760	—	—	72	19	35	6·1	*245*	*4·9*
Sleaford	740	677	—	—	48	3	12	2·0	*75*	*1·9*
Spalding	663	586	—	—	58	5	14	2·9	*121*	*3·3*
Spilsby	790	690	—	—	69	4	27	3·9	*244*	*6·0*
Stamford	498	424	—	—	47	1	26	5·4	*73*	*2·7*
MIDDLESEX (Extra-Metropolitan).										
Brentford	3,585	3,021	11	—	331	49	191	6·7	*958*	*5·8*
Edmonton	5,871	4,930	24	—	443	73	401	8·1	*1,340*	*5·7*
Hendon	2,073	1,597	15	—	174	11	276	13·1	*441*	*5·0*
Staines	729	641	—	—	44	11	33	6·1	*196*	*5·4*
Uxbridge	890	798	—	—	62	7	23	3·4	*72*	*1·7*
MONMOUTH.										
Abergavenny	771	694	—	—	70	2	5	0·9	*60*	*1·6*
Bedwelty	2,183	1,884	—	—	223	17	59	3·5	*323*	*3·1*
Chepstow	647	573	2	—	43	9	20	4·5	*92*	*3·2*
Monmouth	920	820	1	—	84	3	12	1·6	*125*	*2·6*
Newport	2,725	2,445	3	—	221	9	49	2·1	*222*	*1·7*
Pontypool	1,255	1,096	1	—	104	4	50	4·3	*433*	*6·9*
NORFOLK.										
Aylsham	538	479	1	—	48	6	4	1·9	*216*	*7·9*
Blofield	395	338	1	—	45	3	8	2·8	*31*	*1·8*
Depwade	661	564	2	—	63	10	22	4·8	*167*	*5·8*
Docking	493	444	—	—	41	4	4	1·6	*50*	*1·9*
Downham	527	471	—	—	44	5	7	2·3	*48*	*1·6*
Erpingham	584	505	—	—	46	7	26	5·7	*97*	*3·2*
Faith, St.	397	341	2	—	40	1	13	3·5	*21*	*1·2*
Flegg, East and West	343	282	1	—	48	—	12	3·5	*36*	*2·1*
Forehoe	364	322	—	—	38	—	4	1·1	*51*	*3·0*
Freebridge Lynn	368	339	—	—	19	3	7	2·7	*70*	*3·5*
Guiltcross	301	269	—	—	24	3	5	2·7	*44*	*2·8*
Henstead	322	288	—	—	27	3	4	2·2	*48*	*3·0*
King's Lynn	618	529	—	—	60	4	25	4·7	*84*	*2·9*
Loddon and Clavering	429	378	—	—	44	1	6	1·6	*42*	*2·1*
Mitford and Launditch	841	752	—	—	75	7	7	1·7	*56*	*1·3*
Norwich	3,070	2,545	5	—	333	43	144	6·1	*879*	*2·6*
Smallburgh	462	402	2	—	41	5	12	3·7	*46*	*2·1*
Swaffham	362	324	—	—	27	3	8	3·0	*69*	*3·6*
Thetford	519	453	—	—	45	7	14	4·0	*96*	*3·5*
Walsingham	607	539	2	—	50	6	10	2·6	*94*	*3·3*
Wayland	333	292	—	—	28		4	3·9	*48*	*2·8*
Yarmouth, Great	1,230	1,035	—	—	132	28	35	5·1	*180*	*3·0*

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NORTHAMPTON.										
Brackley	339	298	—	—	22	4	15	5·7	*137*	*7·8*
Brixworth	379	340	—	—	30	1	8	2·4	*40*	*2·1*
Daventry	549	500	1	—	34	1	13	2·5	*65*	*2·4*
Hardingstone	325	290	1	—	24	6	4	3·1	*57*	*3·2*
Kettering	1,010	889	1	—	90	10	20	3·0	*145*	*3·1*
Northampton	2,440	1,992	3	—	249	5	191	8·0	*1,186*	*10·4*
Oundle	379	345	—	—	31	1	2	0·8	*39*	*1·9*
Peterborough	1,404	1,275	1	—	97	4	27	2·2	*119*	*1·7*
Potterspury	370	314	—	—	36	14	6	5·4	*64*	*3·2*
Thrapston	459	397	—	—	37	2	23	5·4	*60*	*2·4*
Towcester	362	328	—	—	25	4	5	2·5	*51*	*2·6*
Wellingborough	1,392	1,134	1	—	129	43	85	9·2	*376*	*5·8*
NORTHUMBERLAND.										
Alnwick	602	537	—	—	49	5	11	2·7	*129*	*4·0*
Belford	128	116	—	—	10	2	—	1·6	*7*	*0·9*
Bellingham	144	131	—	—	9	—	4	2·8	*28*	*3·3*
Berwick-on-Tweed	627	555	—	—	59	11	2	2·1	*71*	*2·1*
Castle Ward	671	600	1	—	55	2	13	2·2	*143*	*4·5*
Glendale	265	243	—	—	20	1	1	0·8	*19*	*1·2*
Haltwhistle	251	235	—	—	9	7	—	2·8	*25*	*2·0*
Hexham	996	874	—	—	80	12	30	4·2	*252*	*4·6*
Morpeth	1,392	1,155	—	—	206	11	20	2·2	*130*	*1·8*
Newcastle-on-Tyne	5,754	5,029	7	—	618	46	54	1·7	*814*	*2·9*
Rothbury	152	130	—	—	15	2	5	4·6	*19*	*2·1*
Tynemouth	4,452	3,806	4	2	460	80	100	4·0	*997*	*4·7*
NOTTINGHAM.										
Basford	5,323	4,488	8	—	566	77	184	4·9	*1,006*	*4·2*
Bingham	390	344	5	—	22	6	13	4·9	*56*	*2·5*
East Retford	703	622	—	—	71	2	8	1·4	*72*	*1·9*
Mansfield	1,781	1,509	1	—	218	1	52	3·0	*432*	*4·9*
Newark	1,014	904	—	—	77	3	30	3·3	*135*	*2·7*
Nottingham	6,566	5,039	7	—	809	11	700	10·8	*2,326*	*9·1*
Southwell	583	527	1	—	44	—	11	1·9	*85*	*3·0*
Worksop	1,057	951	4	—	86	4	12	1·5	*119*	*2·2*
OXFORD.										
Banbury	906	706	—	—	103	20	77	10·7	*774*	*17·2*
Bicester	425	376	1	—	34	2	12	3·3	*77*	*3·6*
Chipping Norton	567	490	1	—	53	14	9	4·1	*88*	*3·1*
Headington	905	803	2	—	70	20	10	3·3	*84*	*1·9*
Henley	596	545	—	—	29	3	19	3·7	*106*	*3·5*
Oxford	659	549	2	—	73	10	25	5·3	*120*	*3·4*
Thame	411	363	1	—	33	4	10	3·4	*47*	*2·2*
Witney	705	640	—	—	49	9	7	2·3	*58*	*1·7*
Woodstock	395	345	—	—	36	1	13	3·5	*67*	*3·2*
RUTLAND.										
Oakham	366	324	—	—	35	2	5	1·9	*31*	*1·9*
Uppingham	358	321	—	—	25	2	10	3·4	*94*	*5·0*

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SALOP.										
Atcham	1,338	1,154	—	—	111	24	49	5·5	*252*	*3·6*
Bridgnorth	394	351	—	—	31	4	8	3·0	*86*	*4·0*
Church Stretton	138	127	—	—	8	—	3	2·2	*15*	*2·0*
Cleobury Mortimer	239	213	—	—	20	3	3	2·5	*24*	*2·0*
Clun	287	236	—	—	26	1	24	8·7	*73*	*4·8*
Drayton	363	322	—	—	38	1	2	0·8	*51*	*2·4*
Ellesmere	341	308	—	—	30	—	3	0·9	*26*	*1·4*
Ludlow	557	487	—	—	48	7	15	3·9	*166*	*6·0*
Madeley	817	733	2	—	61	4	17	2·6	*108*	*2·4*
Newport	423	372	—	—	44	1	6	1·7	*40*	*1·6*
Oswestry	794	734	1	—	49	2	8	1·3	*67*	*1·7*
Shifnal	368	327	—	—	31	—	10	2·7	*84*	*4·5*
Wellington	852	762	—	—	73	5	12	2·0	*77*	*1·7*
Wem	280	262	—	—	16	—	2	0·7	*29*	*2·1*
Whitchurch	306	272	—	—	26	2	6	2·6	*45*	*2·6*
SOMERSET.										
Axbridge	1,118	1,008	3	—	64	12	31	3·8	*203*	*3·4*
Bath	1,830	1,514	—	—	200	37	79	6·3	*481*	*5·1*
Bedminster	2,450	2,131	2	—	254	20	43	2·6	*334*	*2·7*
Bridgwater	971	868	3	—	56	16	28	4·5	*175*	*3·4*
Chard	805	694	1	—	75	19	16	4·3	*161*	*3·8*
Clutton	781	698	2	—	59	6	16	2·8	*37*	*0·9*
Dulverton	139	127	—	—	9	1	2	2·2	*15*	*1·9*
Frome	682	615	—	—	52	—	15	2·2	*100*	*2·8*
Keynsham	891	803	—	—	62	10	16	2·9	*114*	*2·5*
Langport	418	372	—	—	31	5	10	3·6	*65*	*2·9*
Shepton Mallet	443	404	—	—	36	—	3	0·7	*54*	*2·3*
Taunton	1,053	912	1	—	96	6	8	1·3	*96*	*1·8*
Wellington	511	464	1	—	41	—	5	1·0	*33*	*1·2*
Wells	646	574	1	—	50	11	10	3·3	*116*	*3·5*
Williton	506	464	—	—	28	2	12	2·8	*64*	*2·3*
Wincanton	572	520	—	—	34	5	13	3·1	*76*	*2·5*
Yeovil	794	691	—	—	63	9	31	5·0	*190*	*4·5*
SOUTHAMPTON.										
Alresford	199	178	—	—	13	3	5	4·0	*33*	*3·2*
Alton	455	405	—	—	35	1	14	3·3	*79*	*3·3*
Alverstoke	769	715	2	—	46	1	5	0·8	*43*	*1·2*
Andover	441	379	—	—	34	10	18	6·3	*83*	*3·5*
Basingstoke	606	528	1	—	41	13	23	5·9	*215*	*6·9*
Catherington	67	59	1	—	3	1	3	6·0	*34*	*8·9*
Christchurch	962	851	2	—	62	25	22	4·9	*218*	*5·1*
Droxford	309	280	1	—	22	2	4	1·9	*43*	*2·6*
Farcham	514	466	—	—	34	4	10	2·7	*54*	*2·3*
Fordingbridge	187	171	—	—	11	—	5	2·7	*16*	*1·7*
Hartley Wintney	520	462	—	—	40	7	11	3·5	*99*	*3·6*
Havant	255	233	—	—	19	—	3	1·2	*40*	*3·1*
Hursley	80	74	—	—	5	—	1	1·3	*5*	*1·3*
Kingsclere	268	237	—	—	24	4	3	2·6	*30*	*2·3*
Lymington	373	337	—	—	16	16	4	5·4	*95*	*5·3*
New Forest	369	316	1	—	30	5	17	6·0	*81*	*4·4*
Petersfield	318	289	1	—	17	4	7	3·5	*48*	*3·0*
Portsea Island	4,646	4,188	9	—	364	21	64	1·8	*395*	*1·8*
Ringwood	155	144	—	—	10	1	—	0·6	*10*	*1·3*
Romsey	302	269	—	—	21	3	9	4·0	*63*	*3·8*
Southampton	1,874	1,523	1	—	190	25	135	8·5	*604*	*6·9*
South Stoneham	1,452	1,265	1	—	81	21	84	7·2	*365*	*5·5*
Stockbridge	183	162	—	—	13	5	3	4·3	*25*	*2·5*
Whitchurch	171	152	—	—	10	2	7	5·3	*42*	*4·8*
Wight, Isle of	1,997	1,770	3	—	121	34	69	5·2	*483*	*4·6*
Winchester, New	863	795	2	—	46	5	15	2·3	*72*	*1·7*

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STAFFORD.										
Wolstanton and Burslem	3,126	2,766	1	—	356	1	2	0·1	*118*	*0·8*
Burton-on-Trent	2,881	2,406	1	—	271	31	172	7·0	*1,185*	*8·2*
Cannock	1,415	1,236	—	—	144	1	34	2·5	*243*	*3·5*
Cheadle	761	667	—	—	69	4	21	3·3	*92*	*2·4*
Leek	1,076	956	1	—	95	8	16	2·2	*212*	*3·9*
Lichfield	1,291	1,145	2	—	110	8	26	2·6	*215*	*3·3*
Newcastle-under-Lyme	1,279	1,120	—	—	119	2	38	3·1	*275*	*4·3*
Seisdon	484	438	—	—	30	2	14	3·3	*64*	*2·5*
Stafford	1,015	884	—	—	86	3	42	4·4	*186*	*3·7*
Stoke-upon-Trent	4,429	3,675	1	—	578	18	157	4·0	*907*	*4·3*
Stone	991	869	—	—	99	1	22	2·3	*112*	*2·3*
Tamworth	711	631	—	—	57	3	20	3·2	*145*	*4·0*
Uttoxeter	397	371	—	—	20	—	6	1·5	*31*	*1·5*
Walsall	3,582	3,029	—	3	393	23	134	4·4	*645*	*3·7*
West Bromwich	4,913	4,353	6	8	495	9	42	1·0	*486*	*2·0*
Wolverhampton	4,973	4,302	5	3	518	7	138	2·9	*744*	*3·0*
SUFFOLK.										
Blything	777	701	—	—	55	2	19	2·7	*132*	*3·2*
Bosmere and Claydon	502	408	—	—	38	—	56	11·2	*129*	*5·4*
Bury St. Edmunds	501	433	—	—	44	6	18	4·8	*73*	*3·0*
Cosford	499	445	—	—	45	4	5	1·8	*60*	*3·4*
Hartismere	471	431	—	—	27	8	5	2·8	*53*	*2·1*
Hoxne	374	323	—	—	39	2	10	3·2	*50*	*2·5*
Ipswich	1,756	1,425	2	—	163	58	108	9·5	*521*	*6·3*
Mildenhall	294	256	—	—	30	—	8	2·7	*47*	*3·1*
Mutford and Lothingland	1,510	1,363	1	—	116	13	17	2·0	*154*	*2·1*
Plomesgate	612	535	2	—	53	4	18	3·6	*106*	*3·4*
Risbridge	598	546	1	—	45	3	3	1·0	*41*	*1·4*
Samford	332	298	—	—	25	1	8	2·7	*47*	*2·6*
Stow	634	572	—	—	53	2	7	1·4	*49*	*1·5*
Sudbury	964	860	—	—	82	5	17	2·3	*140*	*3·1*
Thingoe	493	443	—	—	39	2	9	2·2	*50*	*2·0*
Wangford	435	384	—	—	41	—	10	2·3	*48*	*2·1*
Woodbridge	641	562	1	—	52	12	14	4·1	*83*	*2·4*
SURREY (Extra-Metropolitan).										
Chertsey	817	690	1	—	59	28	39	8·2	*281*	*7·0*
Croydon	3,987	3,278	7	—	326	58	318	9·4	*1,532*	*8·4*
Dorking	472	431	—	—	30	2	9	2·3	*57*	*4·5*
Epsom	1,149	967	—	—	98	39	45	7·3	*375*	*6·7*
Farnham	1,421	1,240	1	—	114	11	55	4·6	*321*	*4·3*
Godstone	443	402	—	—	27	3	11	3·2	*79*	*3·6*
Guildford	1,284	1,186	—	—	71	10	17	2·1	*118*	*1·9*
Hambledon	489	451	1	—	28	1	8	1·8	*48*	*2·0*
Kingston	2,567	2,322	2	—	211	14	18	1·2	*214*	*1·8*
Reigate	926	839	1	—	59	13	14	2·9	*95*	*2·1*
Richmond	1,080	971	4	—	82	1	22	2·1	*72*	*1·4*
SUSSEX.										
Battle	447	409	—	—	26	3	9	2·7	*78*	*3·3*
Brighton	2,917	2,493	5	—	285	35	99	4·6	*489*	*3·4*
Chailey	283	255	—	—	16	2	10	4·2	*58*	*4·2*
Chichester	250	217	—	—	19	6	8	5·6	*100*	*8·3*
Cuckfield	680	595	—	—	47	11	27	5·6	*132*	*5·2*
Eastbourne	1,023	815	2	—	88	14	104	11·5	*293*	*7·0*
East Grinstead	584	507	—	—	45	11	21	5·5	*133*	*4·6*
East Preston	770	677	—	—	63	12	18	3·9	*113*	*3·0*

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SUSSEX—*cont.*										
Hailsham	437	379	—	—	42	3	13	3·7	*117*	*5·2*
Hastings	1,436	1,190	1	—	122	35	88	8·5	*645*	*9·2*
Horsham	753	681	1	—	42	1	28	3·9	*130*	*3·7*
Lewes	342	279	—	—	35	2	26	8·2	*112*	*6·9*
Midhurst	404	376	—	—	24	—	4	1·0	*36*	*1·7*
Newhaven	291	254	—	—	29	1	7	2·7	*56*	*4·3*
Petworth	261	239	—	—	17	3	2	1·9	*33*	*2·3*
Rye	355	321	1	—	19	—	14	3·9	*42*	*2·2*
Steyning	1,500	1,321	4	—	112	18	45	4·2	*363*	*5·0*
Thakeham	231	211	—	—	13	5	2	3·0	*31*	*2·4*
Ticehurst	548	481	—	—	42	5	20	4·6	*92*	*3·4*
Uckfield	652	591	—	—	39	11	11	3·4	*97*	*2·8*
Westbourne	215	185	—	—	15	—	15	7·0	*38*	*3·4*
West Firle	69	62	—	—	4	2	1	4·3	*13*	*4·0*
Westhampnett	576	524	2	—	33	6	11	3·0	*95*	*3·4*
WARWICK.										
Alcester	604	543	—	—	51	3	7	1·7	*97*	*3·0*
Aston	8,296	6,910	7	—	869	67	443	6·1	*2,855*	*6·9*
Atherstone	526	461	—	—	50	1	14	2·9	*66*	*2·5*
Birmingham	8,854	7,867	11	2	845	20	109	1·5	*1,451*	*3·1*
Coventry	1,562	1,376	1	—	143	15	27	2·7	*192*	*2·6*
Foleshill	644	536	—	—	77	11	20	4·8	*31*	*0·9*
Meriden	308	285	—	—	10	9	4	4·2	*30*	*2·1*
Nuneaton	501	422	—	—	60	4	15	3·8	*76*	*3·1*
Rugby	832	740	1	—	73	1	17	2·2	*127*	*3·0*
Solihull	587	525	1	—	42	5	14	3·2	*139*	*4·8*
Southam	314	280	1	—	28	1	4	1·6	*33*	*2·1*
Stratford-on-Avon	619	557	—	—	38	4	20	3·9	*131*	*3·9*
Warwick	1,433	1,292	—	—	110	5	26	2·2	*156*	*2·2*
WESTMORELAND.										
East Ward	436	392	—	—	35	4	5	2·1	*34*	*1·5*
Kendal	1,311	1,196	3	—	100	7	5	0·9	*95*	*1·5*
West Ward	260	238	—	—	22	—	—	0·0	*6*	*0·5*
WILTS.										
Alderbury	834	741	—	—	57	11	25	4·3	*84*	*2·1*
Amesbury	192	179	—	—	11	—	2	1·0	*12*	*1·1*
Bradford	322	290	—	—	29	—	3	0·9	*13*	*0·7*
Calne	223	200	—	—	12	10	1	4·9	*17*	*1·4*
Chippenham	661	591	1	—	47	12	10	3·3	*66*	*2·0*
Cricklade and Wootton Bassett.	353	309	1	—	34	5	4	2·5	*78*	*4·4*
Devizes	550	504	—	—	27	11	8	3·5	*82*	*2·7*
Highworth and Swindon	1,459	1,284	1	—	118	27	29	3·8	*251*	*3·7*
Malmesbury	432	373	—	—	44	13	2	3·5	*94*	*4·3*
Marlborough	270	248	—	—	20	—	2	0·7	*21*	*1·6*
Melksham	543	490	—	—	38	9	6	2·8	*47*	*1·6*
Mere	185	167	—	—	14	1	3	2·2	*14*	*1·3*
Pewsey	336	302	—	—	27	2	5	2·1	*44*	*2·4*
Tisbury	255	226	1	—	18	3	7	3·9	*21*	*1·6*
Warminster	331	298	—	—	17	6	10	4·8	*64*	*3·4*
Westbury and Whorwelsdown.	284	262	—	—	18	1	3	1·4	*10*	*0·6*
Wilton	297	271	—	—	20	3	3	2·0	*15*	*1·0*

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WORCESTER.										
Bromsgrove	1,060	940	—	—	86	5	29	3·2	*148*	*2·7*
Droitwich	882	783	—	—	77	5	17	2·5	*124*	*3·0*
Dudley	5,866	5,134	7	2	614	11	98	1·9	*929*	*3·2*
Evesham	438	387	—	—	41	1	9	2·3	*89*	*4·0*
Kidderminster	1,355	1,215	1	—	108	3	28	2·3	*80*	*1·2*
King's Norton	3,209	2,892	5	—	269	15	28	1·4	*1,065*	*6·9*
Martley	442	395	—	—	36	2	9	2·5	*48*	*2·1*
Pershore	374	331	—	—	39	—	4	1·1	*29*	*1·4*
Shipston-on-Stour	504	453	—	—	41	2	8	2·0	*82*	*3·0*
Stourbridge	3,026	2,676	—	—	288	8	54	2·0	*437*	*2·8*
Tenbury	196	175	—	—	10	1	10	5·6	*75*	*6·7*
Upton-on-Severn	541	497	—	—	34	2	8	1·3	*70*	*2·6*
Worcester	1,011	840	—	—	129	11	31	4·2	*342*	*6·5*
YORK, East Riding.										
Beverley	736	619	2	—	65	15	35	6·8	*209*	*5·7*
Bridlington	496	427	1	—	55	3	10	2·6	*100*	*3·7*
Driffield	635	548	—	—	66	4	17	3·3	*106*	*3·1*
Howden	455	390	—	—	51	—	14	3·1	*43*	*2·2*
Kingston-upon-Hull	2,782	2,227	7	—	305	9	234	8·7	*691*	*4·8*
Patrington	251	228	—	—	17	—	6	2·4	*41*	*2·9*
Pocklington	413	359	2	—	41	4	7	2·7	*73*	*3·1*
Sculcoates	4,073	3,298	7	—	410	45	313	8·8	*974*	*5·2*
Skirlaugh	266	226	—	—	27	3	10	4·9	*42*	*2·7*
York	2,414	2,019	—	—	237	16	142	6·5	*1,296*	*10·5*
YORK, North Riding.										
Aysgarth	152	132	—	—	17	1	2	2·0	*21*	*2·5*
Bedale	220	205	—	—	12	1	2	1·4	*33*	*2·5*
Easingwold	266	238	1	—	16	1	10	4·1	*24*	*1·8*
Guisborough	1,708	1,502	1	1	152	11	41	3·0	*272*	*3·3*
Helmsley Blackmoor	144	131	—	—	12	—	1	0·7	*10*	*1·1*
Kirkby Moorside	140	122	—	—	11	3	4	5·0	*19*	*2·4*
Leyburn	171	155	—	—	15	—	1	0·6	*21*	*1·8*
Malton	660	569	3	—	51	17	20	5·6	*255*	*6·9*
Middlesbrough	4,284	3,703	3	1	429	50	98	3·5	*612*	*3·3*
Northallerton	363	328	—	—	27	3	5	2·2	*36*	*1·9*
Pickering	344	299	—	—	27	—	18	5·2	*107*	*5·8*
Reeth	109	97	—	—	8	3	1	3·7	*16*	*2·2*
Richmond	382	343	—	—	27	7	5	3·1	*57*	*2·8*
Scarborough	1,279	1,048	5	—	123	23	80	8·1	*428*	*6·2*
Stokesley	346	310	1	—	28	4	3	2·0	*36*	*1·9*
Thirsk	368	323	—	—	21	3	21	6·5	*81*	*3·9*
Whitby	961	836	1	—	85	7	32	4·1	*134*	*3·0*
YORK, West Riding.										
Barnsley	3,338	2,813	—	—	359	17	149	5·0	*1,032*	*6·2*
Bramley	1,993	1,650	6	—	244	18	75	4·7	*325*	*3·2*
Bradford	5,604	4,738	6	—	586	11	263	4·9	*2,328*	*7·4*
Bierley, North	3,991	3,341	6	—	375	41	228	6·7	*1,112*	*5·3*
Dewsbury	5,237	3,684	5	—	508	62	978	20·0	*4,105*	*15·0*
Doncaster	1,962	1,737	2	—	168	28	27	2·8	*222*	*2·3*
Ecclesall Bierlow	4,252	3,656	2	—	394	18	182	4·7	*1,027*	*5·0*
Goole	683	608	4	—	53	5	13	2·6	*96*	*2·7*
Halifax	5,035	4,177	7	—	464	102	285	7·7	*1,222*	*4·6*

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YORK, West Riding—*cont.*										
Hemsworth	433	382	—	—	35	—	16	3·7	*98*	*5·4*
Holbeck	910	806	1	—	91	5	7	1·3	*128*	*2·7*
Huddersfield	4,777	4,267	6	—	456	6	42	1·0	*255*	*1·0*
Hunslet	2,345	2,001	2	—	230	36	76	4·8	*722*	*5·9*
Keighley	1,587	322	—	—	182	4	1,079	68·3	*5,963*	*62·6*
Knaresborough	568	477	—	—	56	11	24	6·2	*214*	*6·6*
Leeds	6,656	5,915	8	—	633	13	87	1·5	*532*	*1·6*
Ouseburn, Great	350	316	1	—	24	1	8	2·6	*27*	*1·5*
Pateley Bridge	254	233	—	—	20	—	1	0·4	*4*	*0·3*
Penistone	556	490	1	—	47	10	8	3·2	*95*	*3·4*
Pontefract	1,000	1,601	4	—	196	12	87	5·2	*573*	*5·7*
Ripon	458	396	—	—	37	10	15	5·4	*123*	*5·1*
Rotherham	3,039	2,553	3	—	311	24	148	5·7	*713*	*4·7*
Saddleworth	697	604	1	—	69	1	22	3·3	*124*	*3·5*
Sedbergh	106	94	—	—	10	1	1	1·9	*14*	*2·*
Selby	475	438	—	—	34	1	2	0·6	*56*	*2·*
Settle	377	339	—	—	32	4	2	1·6	*44*	*2·0*
Sheffield	7,154	5,987	13	2	776	39	337	5·3	*1,908*	*5·3*
Skipton	1,154	994	2	—	95	24	39	5·5	*419*	*6·8*
Tadcaster	790	683	2	—	76	2	27	3·7	*181*	*4·5*
Thorne	436	385	—	—	31	1	19	4·6	*105*	*5·1*
Wakefield	3,383	2,951	3	—	325	24	80	3·1	*939*	*5·5*
Wetherby	436	353	1	—	41	18	23	9·4	*237*	*10·9*
Wharfedale	1,477	1,208	2	—	176	21	70	6·2	*502*	*6·6*
Wortley	1,388	1,178	4	—	127	16	63	5·7	*308*	*4·6*
ANGLESEY.										
Anglesey	379	345	—	—	28	2	4	1·6	*55*	*2·7*
Holyhead	502	448	—	—	43	3	15	3·5	*101*	*3·5*
BRECKNOCK.										
Brecknock	445	395	—	—	42	3	5	1·8	*58*	*2·3*
Builth	259	232	—	—	23	2	2	1·5	*18*	*1·4*
Crickhowell	664	555	—	—	85	13	11	3·6	*167*	*5·3*
Hay	283	240	—	—	29	6	8	4·9	*38*	*2·6*
CARDIGAN.										
Aberayron	314	280	—	—	26	3	5	2·5	*67*	*3·9*
Aberystwith	559	498	—	—	38	6	17	4·1	*168*	*4·8*
Cardigan	449	400	—	—	34	7	8	3·3	*32*	*1·4*
Lampeter	300	266	—	—	31	—	3	1·0	*41*	*2·8*
Tregaron	242	226	—	—	14	—	2	0·8	*57*	*3·9*
CARMARTHEN.										
Carmarthen	1,040	954	—	—	72	7	7	1·3	*65*	*1·2*
Llanelly	1,673	1,492	—	—	145	8	28	2·2	*134*	*1·6*
Llandilo Fawr	553	491	—	—	47	6	9	2·7	*45*	*1·6*
Llandovery	341	296	—	—	36	8	1	2·6	*51*	*2·4*
Newcastle-in-Emlyn	515	474	—	—	37	—	4	0·8	*21*	*0·8*

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CARNARVON.										
Bangor and Beaumaris -	1,088	960	1	—	101	4	22	2·4	*87*	*1·6*
Carnarvon - - -	1,266	1,106	2	—	121	12	25	2·9	*203*	*2·9*
Conway - - -	552	499	1	—	31	4	17	3·8	*106*	*4·0*
Pwllheli - - -	622	524	1	—	72	13	12	4·0	*95*	*2·9*
DENBIGH.										
Llanrwst - - -	376	327	—	—	38	7	4	2·9	*62*	*2·9*
Ruthin - - -	381	340	—	—	37	3	1	1·0	*19*	*1·0*
Wrexham - - -	1,857	1,643	—	—	165	9	40	2·6	*264*	*2·8*
FLINT.										
Asaph, St. - - -	765	679	—	—	61	5	20	3·3	*73*	*1·8*
Hawarden - - -	488	446	—	—	32	7	3	2·0	*54*	*2·0*
Holywell - - -	1,319	1,167	—	—	115	12	25	2·8	*277*	*3·9*
GLAMORGAN.										
Bridgend and Cowbridge -	1,332	1,156	—	—	141	16	19	2·6	*259*	*4·0*
Cardiff - - -	4,369	3,733	5	—	423	14	194	4·8	*1,299*	*6·8*
Gower - - -	320	279	—	—	26	12	3	4·7	*37*	*2·1*
Merthyr Tydfil - -	3,486	3,087	2	—	329	34	34	2·0	*337*	*1·9*
Neath - - -	1,897	1,695	2	—	164	10	26	1·9	*193*	*2·0*
Pontardawe - - -	704	635	—	—	55	11	3	2·0	*81*	*2·2*
Pontypridd - - -	4,163	3,540	—	—	460	62	101	3·9	*707*	*3·9*
Swansea - - -	3,732	3,321	3	—	335	15	58	2·0	*457*	*2·5*
MERIONETH.										
Bala - - - -	156	137	—	—	17	2	—	1·2	*23*	*2·6*
Corwen - - -	450	391	1	—	43	8	7	3·3	*107*	*4·4*
Dolgelley - - -	492	364	—	—	26	6	6	3·0	*44*	*1·9*
Festiniog - - -	979	826	—	—	115	23	15	3·9	*193*	*3·7*
MONTGOMERY.										
Llanfyllin - - -	589	520	—	—	52	10	7	2·9	*92*	*3·2*
Machynlleth - -	284	254	—	—	22	1	7	2·8	*108*	*6·3*
Forden - - -	500	448	—	—	35	9	8	3·4	*112*	*4·2*
Newtown and Llanidloes -	701	599	—	—	62	11	29	5·7	*329*	*8·1*
PEMBROKE.										
Haverfordwest - -	1,045	883	2	—	113	20	27	4·5	*189*	*3·7*
Narberth - - -	560	471	—	—	53	23	13	6·4	*156*	*5·2*
Pembroke - - -	933	807	—	—	85	34	7	4·4	*190*	*3·9*
RADNOR.										
Knighton - - -	353	290	—	—	29	7	7	4·2	*75*	*4·2*
Rhayader - - -	179	159	—	—	18	—	2	1·1	*35*	*3·4*

No. 2.

App A. No. 2. Inspection of Public Vaccination.

List (alphabetically arranged) of 287 Unions inspected during the Year 1885, with reference to the Proceedings under the Vaccination Acts, 1867 and 1871, and an Account of the Awards made to the respective Public Vaccinators out of Moneys voted by Parliament for that Purpose.

UNION.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.	Range of Awards in each Union. Minimum.	Range of Awards in each Union. Maximum.	Total Sum awarded in each Union.	Inspector.
			£ s. d.	£ s. d.	£ s. d.	
Alcester	5	2	6 9 0	8 9 0	14 18 0	Dr. Parsons.
Alston-with-Garrigill	2	1	—	—	5 0 0	Mr. Royle.
Altrincham	6	4	7 15 0	33 3 0	64 12 0	Do.
Amersham	6	3	9 0 0	27 0 0	46 0 0	„ Power.
Anglesey	3	3	6 11 0	14 9 0	29 5 0	Dr. Parsons.
Asaph, St.	5	—	—	—	—	Do.
Ashbourne	7	5	1 9 0	14 14 0	36 19 0	Mr. Collins.
Ashford, East	6	6	1 13 0	10 3 0	33 11 0	Dr. Stevens.
Ashford, West	3	3	5 2 0	20 16 0	38 6 0	Do.
Ashton-under-Lyne	12	6	5 7 0	44 16 0	146 9 0	Mr. Royle.
Aston	7	6	7 15 0	97 14 0	346 0 0	Dr. Parsons.
Atherstone	2	1	—	—	17 14 0	Do.
Aylesbury	7	4	3 15 0	13 6 0	37 18 0	Mr. Power.
Axminster	12	2	10 15 0	13 5 0	24 0 0	„ Sweeting.
Aysgarth	2	1	—	—	7 10 0	„ Collins.
Bakewell	8	8	2 13 0	14 16 0	60 18 0	Do.
Bala	1	1	—	—	11 8 0	Dr. Parsons.
Bangor and Beaumaris	5	—	—	—	—	Do.
Barnstaple	10	7	1 0 0	38 15 0	80 1 0	Mr. Sweeting.
Barton Regis	6	4	23 12 0	81 18 0	197 5 0	Dr. Blaxall.
Basford	13	9	3 1 0	56 11 0	256 13 0	Mr. Royle.
Bath	5	2	12 3 0	16 5 0	28 8 0	Dr. Blaxall.
Battle	6	5	1 9 0	13 4 0	31 17 0	„ Stevens.
Beaminster	5	2	1 12 0	6 16 0	8 8 0	„ Gresswell.
Bedale	3	3	5 11 0	18 2 0	31 7 0	Mr. Collins.
Bedford	8	8	3 17 0	29 19 0	81 8 0	„ Power.
Bedminster	9	5	1 6 0	62 1 0	77 3 0	Dr. Blaxall.
Belper	8	9	2 18 0	33 10 0	131 1 0	Mr. Collins.
Bethnal Green	2	2	75 10 0	195 7 0	270 17 0	Dr. Stevens.
Beverley	5	3	5 8 0	33 17 0	45 3 0	Mr. Collins.
Bideford	7	3	8 9 0	18 6 0	37 17 0	„ Sweeting.
Bierley, North	13	8	7 7 0	31 7 0	146 4 0	„ Collins.
Bingham	4	3	10 1 0	14 2 0	37 19 0	„ Royle.
Birmingham	1	1	—	—	224 12 0	Dr. Stevens.
Blandford	4	2	3 2 0	5 9 0	8 11 0	„ Gresswell.
Blean	4	4	4 11 0	16 2 0	36 11 0	„ Stevens.
Bootle	3	3	4 11 0	18 10 0	28 3 0	Mr. Royle.
Boston	8	7	0 19 0	19 11 0	47 1 0	„ Collins.
Brackley	4	3	3 16 0	4 13 0	12 9 0	Dr. Gresswell.
Bradford (Yorkshire)	4	4	41 6 0	67 19 0	223 2 0	Mr. Collins.
Brampton	1	—	—	—	—	„ Royle.
Bridge	5	5	3 6 0	9 5 0	28 18 0	Dr. Stevens.
Bridlington	4	1	—	—	1 3 0	Mr. Collins.
Bridport	4	2	5 0 0	23 6 0	28 6 0	Dr. Gresswell.
Brighton	2	2	44 17 0	45 12 0	90 9 0	„ Stevens.
Bristol	1	1	—	—	42 2 0	Do.
Brixworth	6	1	—	—	6 10 0	„ Gresswell.
Bromley	5	4	2 11 0	26 3 0	55 0 0	„ Stevens.
Burton-on-Trent	8	4	6 16 0	51 8 0	109 3 0	„ Parsons.
Bury St. Edmunds	1	1	—	—	27 11 0	„ Airy.
Buckingham	3	3	3 2 0	16 14 0	29 2 0	Mr. Power.

UNION.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.	Range of Awards in each Union. Minimum.	Range of Awards in each Union. Maximum.	Total Sum awarded in each Union.	Inspector.
			£ s. d.	£ s. d.	£ s. d.	
Caistor	10	5	3 19 0	125 10 0	155 19 0	Mr. Collins.
Camberwell	5	5	2 5 0	94 9 6	285 3 0	Dr. Stevens.
Camelford	2	1	—	—	12 11 0	Mr. Royle.
Canterbury	1	1	—	—	24 6 0	Dr. Stevens.
Carlisle	5	4	3 9 0	67 4 0	86 10 0	Mr. Royle.
Carnarvon	4	1	—	—	30 6 0	Dr. Parsons.
Catherington	1	1	—	—	3 5 0	„ Stevens.
Chailey	4	4	0 19 0	8 14 0	19 2 0	Do.
Chapel-en-le-Frith	3	3	2 10 0	16 1 0	30 6 0	Mr. Collins.
Cheadle	5	1	—	—	9 10 0	Dr. Parsons.
Chelsea	2	2	38 8 0	91 3 0	129 11 0	„ Stevens.
Chester	3	1	—	—	7 17 0	Mr. Royle.
Chesterfield	11	9	13 16 0	38 9 0	205 1 0	„ Collins.
Chichester	1	1	—	—	10 4 0	Dr. Stevens.
Chorlton	11	7	8 9 0	80 7 0	304 8 0	Mr. Royle.
Clutton	5	2	12 15 0	32 13 0	45 8 0	Dr. Blaxall.
Cockermouth	5	2	34 18 0	57 3 0	92 1 0	Mr. Royle.
Congleton	4	3	6 11 0	42 14 0	69 14 0	Dr. Page.
Conway	2	1	—	—	20 18 0	„ Parsons.
Cookham	4	3	1 11 0	17 1 0	34 0 0	„ Stevens.
Corwen	3	—	—	—	—	„ Parsons.
Cranbrook	6	5	2 4 0	5 14 0	18 10 0	„ Stevens.
Crediton	11	2	2 9 0	8 0 0	10 9 0	Mr. Sweeting.
Cuckfield	6	5	2 0 0	8 18 0	36 7 0	Dr. Stevens.
Dartford	5	5	17 3 0	26 2 0	103 7 0	Do.
Daventry	6	2	3 14 0	5 19 0	9 13 0	„ Gresswell.
Dewsbury	11	7	10 0 0	19 7 0	99 11 0	„ Barry.
Dolgelley	5	3	3 13 0	8 15 0	16 15 0	„ Parsons.
Doncaster	7	6	4 19 0	53 0 0	149 12 0	Mr. Collins.
Dorchester	6	4	0 19 0	5 11 0	13 13 0	Dr. Gresswell.
Dover	4	4	2 7 0	42 2 0	57 14 0	„ Stevens.
Driffield	8	2	3 5 0	7 9 0	10 14 0	Mr. Collins.
Easingwold	4	3	2 7 0	11 10 0	23 2 0	Do.
Eastbourne	4	3	3 19 0	40 1 0	48 1 0	Dr. Stevens.
East Grinstead	6	6	3 12 0	9 9 0	43 18 0	Do.
East Hampstead	4	4	3 19 0	14 1 0	30 4 0	Do.
East Preston	3	3	6 15 0	20 17 0	40 3 0	Do.
East Retford	6	2	3 10 0	11 14 0	15 4 0	Mr. Royle.
Eastry	7	5	3 10 0	17 13 0	45 12 0	Dr. Stevens.
East Stonehouse	1	1	—	—	65 2 0	Mr. Sweeting.
East Ward	6	1	—	—	4 15 0	„ Royle.
Elham	5	4	2 15 0	39 12 0	61 2 0	Dr. Stevens.
Eton	8	4	5 2 0	19 9 0	56 8 0	Mr. Power.
Exeter	1	1	—	—	48 19 0	Dr. Stevens.
Faversham	4	3	4 17 0	38 7 0	57 5 0	Do.
Festiniog	3	1	—	—	6 6 0	„ Parsons.
Foleshill	5	1	—	—	8 9 0	Do.
Forden	4	2	7 0 0	7 15 0	14 15 0	Do.
Gainsborough	8	7	1 11 0	38 5 0	63 13 0	Mr. Collins.
George, St., in-the-East	1	1	—	—	111 3 0	Dr. Stevens.
Germans, St.	6	5	3 4 0	7 16 0	31 1 0	Mr. Royle.
Glandford Brigg	9	6	6 17 0	21 19 0	88 18 0	„ Collins.
Glossop	2	—	—	—	—	Do.
Goole	5	2	4 2 0	9 17 0	13 19 0	Do.
Gravesend and Milton	1	1	—	—	30 6 0	Dr. Stevens.
Guisborough	7	2	33 8 0	33 8 0	66 16 0	Mr. Collins.

App. A. No. 2.

Inspection of Public Vaccination.

UNION.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.	Range of Awards in each Union. Minimum.			Range of Awards in each Union. Maximum.			Total Sum awarded in each Union.			Inspector.
			£	s.	d.	£	s.	d.	£	s.	d.	
Hackney	4	4	22	15	0	64	19	0	181	10	0	Dr. Stevens
Hailsham	7	7	3	2	0	5	7	0	30	18	0	Do.
Hardingstone	3	2	6	10	0	8	16	0	15	6	0	„ Gresswell.
Haslingden	6	4	13	14	0	28	3	0	89	2	0	Mr. Royle.
Hastings	2	2	2	6	0	53	7	0	55	13	0	Dr. Stevens.
Havant	4	2	4	12	0	9	17	0	14	9	0	Do.
Hawarden	3	2	0	11	0	13	12	0	14	3	0	„ Parsons.
Hayfield	1	1		—			—		21	19	0	Mr. Collins.
Helmsley Blackmoor	2	1		—			—		13	17	0	Dr. Barry.
Hemsworth	4	3	4	2	0	30	0	0	49	2	0	Mr. Collins.
Hollingbourn	6	5	1	6	0	8	0	0	23	17	0	Dr. Stevens.
Holsworthy	5	2	2	2	0	15	0	0	17	2	0	Mr. Sweeting.
Holyhead	3	3	9	16	0	14	18	0	34	16	0	Dr. Parsons.
Holywell	5	2	23	0	0	31	15	0	54	15	0	Do.
Honiton	12	5	2	13	0	19	17	0	65	5	0	Mr. Sweeting.
Hoo	1	1		—			—		11	8	0	Dr. Stevens.
Horncastle	6	6	7	18	0	15	14	0	63	6	0	Mr. Collins.
Horsham	8	7	1	9	0	13	15	0	37	18	0	Dr. Stevens.
Howden	4	1		—			—		12	5	0	Mr. Collins.
Huddersfield	16	8	11	11	0	35	11	0	158	4	0	Do.
Hunslet	3	3	2	8	0	86	5	0	101	7	0	Do.
Huntingdon	5	3	5	11	0	10	6	0	23	0	0	Dr. Airy.
Islington	5	5	33	18	0	70	18	0	247	1	0	„ Stevens.
Ives, St. (Hunts).	5	4	1	17	0	9	13	0	26	10	0	„ Airy.
Keighley	4	4	0	18	0	12	10	0	18	1	0	„ Barry.
Kendal	8	6	2	14	0	9	14	0	40	5	0	Mr. Royle.
Kettering	4	3	2	14	0	35	5	0	49	15	0	Dr. Gresswell.
Keynsham	1	1		—			—		84	1	0	„ Blaxall.
Kingsbridge	5	4	4	11	0	33	7	0	56	5	0	Mr. Sweeting.
Kingston-upon-Hull	2	2	25	16	0	57	19	0	83	15	0	Dr. Barry.
Kirkby Moorside	1	1		—			—		11	9	0	Do.
Knaresborough	3	2	6	11	0	16	8	0	22	19	0	Mr. Collins.
Lambeth	5	5	24	6	0	101	19	0	322	2	0	Dr. Stevens
Langport	6	2	8	4	0	11	4	0	19	8	0	„ Gresswell.
Launceston	8	5	2	13	0	6	13	0	23	0	0	Mr. Royle.
Leeds	7	7	1	12	0	53	19	0	174	9	0	Dr. Stevens.
Leek	5	2	6	12	0	14	17	0	21	9	0	„ Parsons.
Leighton Buzzard	2	2	1	16	0	29	6	0	31	2	0	Mr. Power.
Lewes	1	1		—			—		14	2	0	Dr. Stevens.
Lewisham	5	5	7	7	0	23	12	0	86	15	0	Do.
Leyburn	6	4	3	0	0	7	13	0	18	7	0	Mr. Collins.
Lincoln	11	9	2	9	0	41	7	0	92	0	0	Do.
Liskeard	6	2	7	15	0	10	17	0	18	12	0	„ Royle.
Liverpool	3	3	41	10	0	78	0	0	175	17	0	Dr. Stevens.
Llanfyllin	5	—		—			—			—		„ Parsons.
Llanrwst	2	—		—			—			—		Do.
London, City of	2	2	19	2	0	20	7	0	39	9	0	„ Stevens.
Lougtown	2	1		—			—		10	19	0	Mr. Royle.
Louth	11	8	1	16	0	9	11	0	52	15	0	„ Collins.
Macclesfield	6	6	1	0	0	57	10	0	101	10	0	Dr. Page.
Machynlleth	4	2	6	17	0	6	19	0	13	16	0	„ Parsons.
Malling	4	3	10	5	0	19	3	0	42	0	0	„ Stevens.
Malton	6	2	5	4	0	11	3	0	16	7	0	„ Barry.
Maidstone	5	4	5	12	0	49	13	0	75	12	0	„ Stevens.
Manchester	3	2	59	4	0	59	16	0	119	0	0	Do.
Mansfield	6	5	4	16	0	50	12	0	123	17	0	Mr. Royle.
Marylebone	2	2	58	3	0	123	16	0	181	19	0	Dr. Stevens.
Medway	3	3	30	2	0	56	17	0	134	14	0	Do.
Meriden	3	2	2	11	0	8	6	0	10	17	0	„ Parsons.
Middlesbrough	4	4	18	11	0	182	1	0	309	10	0	„ Barry.
Midhurst	5	5	1	8	0	13	9	0	32	11	0	„ Stevens.
Mildenhall	2	1		—			—		14	18	0	„ Airy.
Mile End Old Town	2	1		—			—		98	11	0	„ Stevens.
Milton	2	2	19	5	0	40	0	0	59	5	0	Do.

UNION.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.	Range of Awards in each Union. Minimum.	Range of Awards in each Union. Maximum.	Total Sum awarded in each Union.	Inspector.
			£ s. d.	£ s. d.	£ s. d.	
Nantwich	8	4	4 12 0	11 0 0	27 15 0	Dr. Page.
Neots, St.	6	4	1 17 0	14 16 0	30 13 0	„ Airy.
Newark	9	5	1 6 0	50 18 0	70 7 0	Mr. Royle.
Newcastle-on-Tyne	3	4	31 8 0	66 12 0	166 18 0	Dr. Stevens.
Newcastle-under-Lyme	3	1	—	—	40 6 0	„ Parsons.
Newhaven	5	5	1 1 0	8 6 0	15 8 0	„ Stevens.
Newport Pagnell	9	3	2 5 0	19 12 0	26 10 0	Mr. Power.
Newton Abbot	11	6	6 18 0	49 3 0	120 3 0	„ Sweeting.
Newtown and Llanidloes	4	2	5 13 0	20 13 0	26 6 0	Dr. Parsons.
Northallerton	4	3	2 7 0	23 17 0	29 13 0	Mr. Collins.
Northampton	4	1	—	—	49 9 0	Dr. Gresswell.
Northwich	6	4	16 17 0	36 9 0	92 4 0	„ Page.
Nottingham	3	3	86 11 0	127 6 0	319 15 0	Mr. Royle.
Nuneaton	2	2	7 13 0	13 16 0	21 9 0	Dr. Parsons.
Oakham	3	1	—	—	9 11 0	Mr. Royle.
Okehampton	6	2	11 9 0	14 17 0	26 6 0	„ Sweeting.
Oundle	4	2	5 17 0	6 9 0	12 6 0	Dr. Gresswell.
Ouseburn, Great	6	5	2 9 0	13 5 0	36 4 0	Mr. Collins.
Paddington	1	2	40 4 0	56 17 0	97 1 0	Dr. Stevens.
Pancras, St.	1	1	—	—	276 3 0	Do.
Pateley Bridge	3	1	—	—	10 1 0	Mr. Collins.
Patrington	5	1	—	—	6 13 0	Do.
Penrith	6	2	3 3 0	7 10 0	10 13 0	Mr. Royle.
Peterborough	7	5	5 5 0	39 5 0	73 9 0	Dr. Gresswell.
Petworth	4	4	2 8 0	8 0 0	23 4 0	„ Stevens.
Pickering	3	1	—	—	8 6 0	„ Barry.
Plymouth	1	2	86 8 0	122 14 0	209 2 0	Mr. Sweeting.
Plympton St. Mary	5	5	11 8 0	15 7 0	64 14 0	Do.
Pocklington	6	2	5 9 0	7 6 0	12 15 0	„ Collins.
Pontefract	7	7	4 17 0	38 4 0	132 4 0	Do.
Poole	4	3	4 4 0	14 11 0	27 2 0	Dr. Gresswell.
Potterspury	4	1	—	—	17 11 0	Do.
Prescot	8	2	73 9 0	93 3 0	166 12 0	Mr. Royle.
Prestwich	5	3	7 16 0	88 12 0	173 13 0	Do.
Pwllheli	5	4	6 14 0	14 2 0	40 10 0	Dr. Parsons.
Reeth	2	2	6 12 0	10 2 0	16 14 0	Mr. Collins.
Richmond (Yorks.)	5	3	5 0 0	11 18 0	23 2 0	Do.
Ripon	4	3	4 8 0	14 4 0	26 10 0	Do.
Rochdale	6	3	2 19 0	81 5 0	96 3 0	„ Royle.
Romney Marsh	3	3	1 0 0	8 18 0	15 12 0	Dr. Stevens.
Rotherham	8	5	10 8 0	71 11 0	162 3 0	„ Barry.
Rugby	8	3	3 5 0	7 17 0	14 9 0	„ Parsons.
Runcorn	4	2	9 5 0	55 5 0	64 10 0	Mr. Royle.
Ruthin	3	3	6 16 0	12 9 0	26 8 0	Dr. Parsons.
Rye	3	3	5 0 0	15 13 0	29 2 0	„ Stevens.
Saddleworth	1	—	—	—	—	„ Barry.
Salforth	3	3	29 1 0	79 15 0	180 16 0	„ Stevens.
Sculcoates	6	4	3 2 0	136 6 0	304 0 0	Mr. Collins.
Sedbergh	2	2	1 11 0	6 9 0	8 0 0	Dr. Barry.
Selby	5	3	1 12 0	30 13 0	39 4 0	Mr. Collins.
Sevenoaks	6	4	3 3 0	10 5 0	29 8 0	Dr. Stevens.
Shardlow	8	6	3 11 0	14 15 0	56 6 0	Mr. Collins.
Sheffield	6	6	14 2 0	53 8 0	196 0 0	Dr. Stevens.
Sheppey	2	2	5 9 0	31 12 0	37 1 0	Do.
Skirlaugh	5	2	1 14 0	4 5 0	5 19 0	Mr. Collins.
Solihull	4	3	4 7 0	11 4 0	21 12 0	Dr. Parsons.
Southam	4	2	8 1 0	11 7 0	19 8 0	Do.
Southmolton	9	6	0 9 0	14 11 0	39 16 0	Mr. Sweeting.
Southwell	7	5	1 12 0	13 14 0	41 10 0	„ Royle.
Spilsby	7	2	11 19 0	12 2 0	24 1 0	„ Collins.
Steyning	6	4	5 6 0	18 15 0	42 13 0	Dr. Stevens.
Stockport	5	2	26 6 0	57 6 0	83 12 0	Mr. Royle.
Stoke Damerel	2	1	—	—	54 15 0	„ Sweeting.
Stokesley	4	3	8 16 0	14 4 0	34 16 0	„ Collins.

App. A. No. 2.

Inspection of Public Vaccination.

UNION.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.	Range of Awards in each Union. Minimum.	Range of Awards in each Union. Maximum.	Total Sum awarded in each Union.	Inspector.
			£ s. d.	£ s. d.	£ s. d.	
Stratford-on-Avon	7	3	7 14 0	16 18 0	34 5 0	Dr. Parsons.
Stratton	2	1	—	—	8 1 0	Mr. Royle.
Strood	2	2	25 8 0	35 12 0	61 0 0	Dr. Stevens.
Sturminster	4	2	4 11 0	9 3 0	13 14 0	„ Gresswell.
Swansea	3	2	34 6 0	125 9 0	159 15 0	„ Parsons.
Tadcaster	5	4	6 13 0	21 5 0	52 7 0	Mr. Collins.
Tamworth	3	1	—	—	19 11 0	Dr. Parsons.
Tarvin	2	1	—	—	20 1 0	Mr. Royle.
Taunton	7	4	3 11 0	8 17 0	28 8 0	Dr. Blaxall.
Tavistock	7	1	—	—	12 9 0	Mr. Sweeting.
Tenterden	6	5	3 7 0	7 1 0	22 15 0	Dr. Stevens.
Thakeham	2	2	4 5 0	10 18 0	15 3 0	Do.
Thanet, Isle of	4	4	7 5 0	42 16 0	93 5 0	Do.
Thomas, St.	17	10	2 7 0	37 13 0	110 2 0	Mr. Sweeting.
Thingoe	8	6	1 1 0	6 1 0	21 15 0	Dr. Airy.
Thirsk	6	4	3 17 0	19 3 0	32 19 0	„ Barry.
Thorne	6	4	3 11 0	6 9 0	20 16 0	Mr. Collins.
Thrapston	5	3	7 14 0	12 15 0	32 12 0	Dr. Gresswell.
Ticehurst	8	7	3 3 0	7 18 0	39 11 0	„ Stevens.
Tiverton	14	4	0 15 0	17 17 0	33 0 0	Mr. Sweeting.
Tonbridge	6	4	9 1 0	26 3 0	64 13 0	Dr. Stevens.
Torrington	5	3	7 4 0	14 19 0	32 9 0	Mr. Sweeting.
Totnes	11	6	3 4 0	33 0 0	75 7 0	Do.
Towcester	4	1	—	—	12 3 0	Dr. Gresswell.
Toxteth Park	2	1	—	—	35 15 0	„ Stevens.
Uckfield	6	5	2 5 0	12 15 0	46 9 0	Do.
Uppingham	4	3	2 3 0	14 19 0	26 5 0	Mr. Royle.
Uttoxeter	5	1	—	—	4 17 0	Dr. Parsons.
Wakefield	6	5	11 7 0	71 9 0	201 16 0	Mr. Collins.
Wandsworth and Clapham.	7	6	12 5 0	110 18 0	283 1 0	Dr. Stevens.
Wareham and Purbeck	7	3	4 17 0	6 7 0	17 0 0	„ Gresswell.
Warwick	3	—	—	—	—	„ Parsons.
Wellingborough	5	3	10 2 0	30 13 0	64 8 0	„ Gresswell.
Westbourne	3	3	1 17 0	7 16 0	14 8 0	„ Stevens.
West Derby	7	6	18 4 0	111 11 0	309 19 0	Do.
West Firle	3	3	1 2 0	2 6 0	4 17 0	Do.
Westhampnett	5	4	4 8 0	14 3 0	32 1 0	Do.
West Ward	4	2	1 17 0	11 14 0	13 11 0	Mr. Royle.
Wetherby	6	3	4 11 0	5 16 0	15 3 0	„ Collins.
Whitby	4	1	—	—	19 10 0	Dr. Barry.
Whitehaven	6	1	—	—	25 8 0	Mr. Royle.
Wigton	7	1	—	—	5 10 0	Do.
Winslow	3	2	7 17 0	8 6 0	16 3 0	„ Power.
Wirral	4	2	18 8 0	24 12 0	43 0 0	„ Royle.
Woburn	3	2	2 12 0	9 3 6	11 15 0	„ Power.
Wolstanton and Burslem	3	3	52 15 0	62 14 0	169 1 0	Dr. Parsons.
Wolverhampton	4	1	—	—	39 13 0	Do.
Woolwich	4	4	5 0 0	55 16 0	115 12 0	„ Stevens.
Worksop	7	6	2 7 0	39 1 0	101 19 0	Mr. Royle.
Wrexham	5	3	6 19 0	82 2 0	97 10 0	Dr. Parsons.
Wycombe	12	5	5 5 0	13 0 0	48 17 0	Mr. Power.
York	6	4	2 3 0	106 0 0	121 14 0	Dr. Barry.
Total	1,433	915	—	—	17,687 3 0	

No. 3.

Statistics of the National Vaccine Establishment and Educational Vaccination Stations.

Ia.—Staff at end of 1885.

N.B.—The Stations named in *italics* are Educational Vaccination Stations authorised by the Local Government Board.

—	Name.	Vaccination Stations.	Days and Hours of Attendance.
Vaccinators supplying lymph for the public service, & salaried from the Parliamentary grant.	1. Dr. R. Cory	*Surrey Chapel*	Tues., Thurs.; 2.
	2. Mr. W. E. G. Pearse	*Tottenham Court Chapel.*	Mon., Wednes.; 1.
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. Mr. Ellis S. Guest	*Manchester*	Monday; 2.
	2–6. Dr. Edmund Robinson.	*Birmingham*	Monday, Tuesday, Wednesday } 11.; Wednesday; 2. Thursday; 11.
	7. Mr. Roger Parker	*Liverpool*	Tuesday; 2.30.
	8. Mr. E. L. Webb	*Pimlico*	Thursday; 10.
	9. Mr. J. Hawthorn	*Newcastle-on-Tyne.*	Wednesday; 3.
	10. Mr. W. E. G. Pearse	*Westminster*	Tuesday; 10.
	11–12. Mr. W. A. Sumner	*Marylebone*	Tuesday; 2. Wednesday; 10.
	13. Mr. C. T. Blackman	*Whitechapel*	Wednesday; 11.
	14. Mr. Frederick Holmes	*Leeds*	Tuesday; 2.30.
	15. Dr. Edward Lynes	Coventry	Tuesday; 12.
	16. Dr. Hugh Thomson	*Glasgow*	Monday; 12.
	17. Mr. Robert W. Dunn	*Strand*	Thursday; 11.
	18. Mr. W. Skinner	*Sheffield*	Tuesday; 3.
	19. Dr. A. C. Clarke	Salford	Thursday; 2.
	20. Dr. G. A. Miskin	Waterloo	Tuesday; 2.
	21. Mr. J. O. Affleck	*Edinburgh*	Wednes., Sat.; 1.
	22. Dr. R. Cory	*St. Thomas's Hosp.*	Wednesday; 11.30.
	23. Dr. D. C. McVail	*Glasgow West*	Monday; 1.
Teachers of Vaccination not supplying lymph	Dr. W. Husband	*Edinburgh*	Wednes., Sat.; 12.
	Dr. R. D. Tannahill	*Glasgow*	Mond., Thurs.; 12.
	Mr. H. Lawrence	*Bristol*	Wednesday; 10.
	Mr. J. Gittins	*Horsleydown*	Monday; 2.
	Mr. William A. Budd	*Exeter*	Thursday; 3.

App. A. No. 3.

National Vaccine Establishment.

I*b*.—Animal Vaccination.

The Animal Vaccine Station is at 95, Lamb's Conduit Street, where Dr. R. Cory and Mr. S. F. Murphy attend for the Vaccination of Children on Tuesdays and Thursdays, at 10.30 a.m.

II.—Sources and Amount of Lymph Supply in 1885.

N B.—The Stations named in *italics* are Educational Vaccination Stations authorised by the Local Government Board.

—	Vaccination Stations.	Number of Vaccinations performed at the Stations respectively.		Number of Charges of Lymph supplied from the Stations respectively.	
		Primary.	Re-vaccinations.	Charged Ivory Points.	Charged Tubes each estimated as equal to 10 Ivory Points.
Vaccinators salaried from the Parliamentary grant.	1. *Surrey Chapel*	323	77	2,686	—
	2. *Tottenham Court Chapel.*	622	48	—	556
	Total -	945	125	2,686	556
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. *Manchester** -	124	—	—	66
	2–6. *Birmingham* -	4,467	259	—	1,596
	7. *Liverpool* -	1,394	—	—	367
	8. *Pimlico* - -	436	131	—	151
	9. *Newcastle-on-Tyne.*	687	7	—	989
	10. *Westminster* -	888	173	—	496
	11–12. *Marylebone* -	1,188	196	—	11
	13. *Whitechapel* -	1,637	22	—	—
	14. *Leeds* - -	1,119	—	—	177
	15. Coventry -	956	2	—	1,857
	16. *Glasgow* -	814	3	—	338
	17. *Strand*† - -	—	—	—	14
	18. *Sheffield* - -	1,104	7	—	132
	19. Salford - -	664	2	—	661
	20. Waterloo -	713	48	—	1,567
	21. *Edinburgh*‡ -	557	4	—	80
	22. *St. Thomas's Hospital.*	374	49	—	30
	23. *Glasgow West*	676	—	—	239
	Total -	17,798	903	—	8,771
	Grand Total	18,743	1,028	2,686	9,327

* Information for one month only received from this station.
† No information received from this station.
‡ For the first six months of the year only.

II.—Sources and Amount of Lymph, &c.—*continued.*

(*b.*) During the year, *additional supplies* (to the extent of 11,785 charged tubes) were obtained from the following gentlemen:—

Mr. C. C. Claremont, Hampstead Road.
Mr. W. Kempster, Battersea East.
Mr. W. Arthur, Kennington.
Mr. H. May, Aston.
Mr. H. W. Newton, Newcastle-on-Tyne.
Mr. W. H. W. Wilkinson, Liverpool Road.
Mr. J. P. Purvis, Greenwich.
Dr. N. E. Roberts, Toxteth Park.
Dr. T. N. Orchard, Pendleton.
Dr. T. M. Johnson, Salford.
Mr. J. W. Kay, St. George's East.
Mr. J. Bark, Kirkdale.
Mr. J. Dalgliesh, Newcastle-on-Tyne.
Mr. J. A. Angus, Newcastle-on-Tyne.
Dr. P. Kavanagh, Deptford.
Dr. M. Greenwood, Haggerston.
Dr. J. B. Buist, Edinburgh.
Dr. C. T. Aveling, Homerton.
Dr. R. S. Archer, Everton.
Mr. A. G. Wells, Fulham.
Dr. W. B. Johnston, Rotherhithe.
Mr. J. W. Hopkins, Leeds.

III.—Distribution of Human Lymph, 1885.

Number of applications:	
From Medical Practitioners in England and Wales	8,287
,, ,, ,, Scotland	243
,, the Army	69
,, the Navy and from the Emigration Department	86
,, India and the Colonies	156
,, Diplomatic and other Foreign Services	44
Total	8,885
Supplies sent out:—	
Charged ivory points	2,671
,, capillary tubes	20,335

IV. Calf-Lymph, 1885.

Number of applications	1,841
Amount received:—	
Charged ivory points	17,164
,, capillary tubes	12
Supplies sent out:—	
Charged ivory points	17,334
,, capillary tubes	12

App. A. No. 4.

Animal Vaccine Stations; by Dr. Cory.

No. 4.

Report on the Proceedings of the Board's Animal Vaccine Stations; with some Experiences as to the Characters of Calf Lymph; by Dr. Cory.

Operations of 1885-6.

During the year from the 1st of April 1885 to the 31st of March 1886, there were 304 calves received at Lamb's Conduit Street, of which 107 females and 193 males were vaccinated, and 4 were returned to the contractor as being ill, and therefore unfit for vaccination purposes. The aggregate weight of the calves, on admission to Lamb's Conduit Street, during that period, was, of males 46,371, of females 26,811 lbs. The aggregate weight of the same calves on leaving was, of males 50,021, of females 27,763 lbs. Thus the calves, so far from losing weight or health through their vaccination, increased in weight by an average 15·1 lbs., the increase in the males amounting on an average to 18·7 lbs., in the females to 8·7 lbs.*

Mr. Murphy, in the report of the station in 1882, gives the general increase as 18·7. The gain of 1882 is not, however, comparable with the gain in 1885, since in the former year the calves came to Lamb's Conduit Street direct from the farmer; and in 1885 they were received there after a preliminary stay in Somers Town, where they had been under special nurture.

All the calves that were operated on proved susceptible to the vaccine inoculation. There were (*a*) 7,783 insertions made on 134 of the calves with lymph taken directly from another calf, vaccinated 120 hours before; producing 7,302 vesicles, which give an insertion success-rate of 93·8 per cent.; and there were (*b*) 4,286 insertions made on 71 of the calves with direct lymph of 96 hours growth, producing 4,029 vesicles, which give an insertion success-rate of 94 per cent.

Other calves were vaccinated with lymph preserved in tubes. This was done each week to meet the requirements of the station; and the occasion has been taken to observe the keeping qualities of such lymph. Of these mention will be made further on in the report.

Children.

During the year 1885–6 there were 4,054 persons primarily vaccinated, of whom 2,054 were males, and 2,000 females.

Susceptibility.

In every case except nine the vaccination succeeded at the first attempt.

There was not a single case of insusceptibility, but all were successfully vaccinated.

> [I may say here that in the whole course of my vaccination experience I have never met with a case of insusceptibility in any child under 10, and with only one case above that age, although it has fallen to my lot to vaccinate many cases of reputedly insusceptible children.]

Insertion success.

Of the 4,054 persons primarily vaccinated, Mr. Murphy vaccinated 208, two of whom did not return for inspection, and one was vaccinated

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* The average increase in girth for the males was ·78 inch, and for the females ·08 inch. All the calves increased in weight except 35, which lost 10 lbs. on an average each, and three calves which neither gained or lost.

round a nævus. Of the 205 of his cases whose inspection is recorded, 203 had taken in five places each, one in four, and one in three, which give an insertion success-rate of 99·7.

Mr. Collins vaccinated 34 cases, 32 of which were successful in five places, one in four places, and one in three places. This gives an insertion success-rate of 98·23 per cent.

Mr. Stott vaccinated 25 cases, 21 of which were successful in 5 places, 4 in four places, showing an insertion success-rate of 96·8 per cent.

I myself vaccinated 3,787 cases, of which 3,480 were successful in five places, 138 in four places, 59 in three places, 35 in two places, 18 in one place. Nine were unsuccessful at the first attempt. Excluding 39 that did not return for inspection and nine vaccinated round nævi, this gives my own insertion success-rate at 97·44 per cent.

Re-vaccinations.

Re-vaccinations :—These numbered 2,882 during the year ; consisting of 1,600 performed at Lamb's Conduit Street, principally by myself, and of 1,282 performed at the Board's temporary station in Southampton Row, principally by Mr. Stott.

More or less of successful result was observed in all but 39 of these re-vaccinations. Of the total applicants for re-vaccination, 910 stated that they had previously been re-vaccinated.

Keeping quality of lymph :

In the course of our operations at Lamb's Conduit Street, we have now attained to some valuable experience respecting the capability of preserving animal lymph. We may first note its keeping powers in the case where it is *used again on the calf*, and the following table will show this for all the time the station has been open. It will be seen that we have established a possibility of preserving lymph in tubes for upwards of two years. It would appear that the reason why at first so much distrust existed about the keeping powers of animal lymph was owing to our chief experience having been derived from Belgium, where it was the practice to take lymph for storage at a later period than 120 hours (five days) after the vaccination of the calf ; at a period, namely, when the lymph was more abundant and less difficult of obtaining ; but we have learned that this lymph more rapidly deteriorates, and is apt to produce spurious results in the same way as human lymph when taken after the eighth day.

for use on calf ;

Length of Time in Days during which Lymph was preserved in Tubes before using.	No. of Insertions made with it on Calves.	Successful Insertion on Calves.	Insertion success-rate per cent.
2	3998	3390	84·7
4	1438	1139	74·2
6 to 8	255	184	72·1
9	431	309	71·6
11 to 12	337	273	70·6
14	263	214	81·3
16	288	207	71·9
17 to 46	639	472	73·8
53 to 93	445	332	74·6
100 to 200	388	258	66·5
200 to 500	104	17	16·3
500 to 600	135	45	33·3
600 to 700	82	24	35·
816 to 858	72	4	5·5

In the above table are included both 120 hours and 96 hours lymph; but none taken later than 120 hours. All the lymph was preserved in tubes.

for use with children;

The following tables detail the result of vaccinating *children* with animal lymph preserved in tubes and upon points respectively. [The lymph, as such, may be taken by the reader of these tables to have been the same in all respects but for the difference in the way of its storage. It included, in equal proportions for the respective methods of storage, lymph of 96 and of 120 hours growth on the calf.] It has been noticed that within four months of storage there seems to be some advantage in points over tubes as a means of utilising calf vaccine with children, and 154 days appears to be the longest interval that should be allowed to elapse between the taking of calf-lymph on points and its use on children. As regards more extended periods of keeping, it is, however, interesting and suggestive to note that (in the few cases observed) lymph preserved in tubes retained its powers better than when kept on points.

stored in tubes and on points.

Results of Vaccination of Children with Calf Lymph, preserved on Points and in Tubes for various Periods.

Mode of Storage.	Time during which Lymph was stored.	Aggregate Number of Insertions made (5 to each Child).	Aggregate Number of successful Insertions.	Per-centage of Insertion success.
Points.	Under 10 days - -	40	34	85
	10–20 days - - -	25	21	84
	20–50 days - - -	70	63	90
	50–100 days - -	70	51	73
	100–154 days - -	60	29	48
	Over 154 days - -	30	0	0
Tubes.	Under 10 days - -	75	65	87
	10–20 days - - -	25	17	68
	20–50 days - - -	65	47	72
	50–100 days - -	45	39	87
	100–154 days - -	20	17	85
	159–280 days - -	40	33	82

In closing this report I have only to add that record has been kept of the descent of the lymph, the weight, sex, and colour of the calf, and the character of the vesicles in the case of every animal, and every vaccination throughout the year.

No. 5.

Abstract of Medical Inspections made in 1885 with regard to the Incidence of Disease on particular places, and to questions concerning Local Sanitary Administration.

1. Bishop Stortford Rural Sanitary District (Hertfordshire); population, 15,097; Mr. R. D. R. Sweeting.

   Sanitary Authority: Bishop Stortford R.*

   Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

   Chief Facts reported: Diphtheria at Braughing in 1883–84 and 1885, and at Little Hallingbury in 1885. In first Braughing epidemic, early cases in dirty and damp houses. Fatal throat disease amongst fowls at farm on which first case worked, and at other farms. Some association of fowl and human throat affections. In second Braughing outbreak, early cases preceded by fatal "croup," by "mumps," and the like in school-goers. Little Hallingbury outbreak sprang up at end of June 1885, and lasted to end of year: first recognised case preceded by sore throat in the same family, but origin of this obscure; house damp, ditch water drunk, and a foul stop-hole adjacent. Disease spread by personal communication and by school-assemblage. Its possible spread in a particular instance by drinking water suggested by the medical officer of health. Ventilation at the schools not perfect. Disinfection of rooms and belongings carried out. A small cottage rented and used as a Sanitary Hospital. Schools kept closed.

2. Bodmin (Cornwall); population, 5,061; Dr. Parsons.

   Sanitary Authority: Bodmin Town Council, U.*

   Ground of Inquiry: To ascertain action taken since previous inspection in 1881.

   Chief Facts reported: Since visit in 1881, increased ventilation has been provided for the sewers, and certain sewers in the neighbourhood of wells have been diverted and relaid; but sources of danger to the purity of public wells still remain. Removal of refuse better carried out. A surveyor appointed. In other respects little action taken. Nuisance at outfall of main sewer. A few W.C.s provided with flushing cisterns, but many connected direct with water service; others flushed by hand only; some in a foul state from insufficient flushing. Nuisances from pig-keeping and accumulations of stable dung. No byelaws. No supervision over erection of new houses. No provision for isolation of cases of infectious disease.

3. Bodmin Rural Sanitary District (Cornwall); population, 12,737; Dr. Parsons.

   Sanitary Authority: Bodmin R.

   Ground of Inquiry: To ascertain action taken since previous inspection in 1881.

* Throughout this abstract "R" denotes "Rural Sanitary Authority," and "U," "Urban Sanitary Authority."

Chief Facts reported: Little action taken. Sewers about to be laid down at Egloshayle Road and Port Isaac: required in other places where the existing means of carrying off waste water are roadside channels, or rough masons' drains. Privy accommodation insufficient; many houses unprovided with any; privies of faulty construction, with offensive cesspits, or built over streams. Pig-keeping nuisances. Houses (often life-hold) unfit for habitation. Neglect of Authority to enforce abatement of nuisances.

4. Brixworth Rural Sanitary District (Northamptonshire); population, 13,336; Dr. Parsons.

Sanitary Authority: Brixworth R.

Ground of Inquiry: Local complaint and insufficient reports of Medical Officer of Health.

Chief Facts reported: Some of the villages sewered with satisfactory results; sewage disposed of on osier beds. Other villages unsewered; sewage going into ditches or leaky highway drains. Ill-constructed house drains. Excrement disposal in the sewered villages by pan-closets, hand-flushed: in the others by offensive cesspit privies. Water supply from springs and wells, frequently exposed to contamination. Nuisances from pig-keeping and accumulations of manure. In some of the villages many of the cottages old, dilapidated, and ill-ventilated. Overcrowding. Appointment of Medical Officer of Health merely nominal.

5. Cheshunt (Middlesex); population, 7,735; Mr. R. D. R. Sweeting.

Sanitary Authority: Cheshunt Local Board, U.

Ground of Inquiry: Diphtheria.—Reports of Medical Officer of Health, and Registrar-General's Returns.

Chief Facts reported: Smart outbreak of diphtheria reported by Medical Officer of Health: eight deaths recorded in quarterly return of Registrar-General for first quarter of 1885. Eighteen families and 41 persons attacked; arranged in two groups according to time of attack, the first group of 30 persons between February 7th and 22nd; and the second of 11 persons between March 23rd and 25th. No condition, such as sanitary circumstances or milk supply, common to first group, but the same school attended by those members of families who were first attacked. Escapes related not only to age, but to non-attendance at a particular school. At this school, dropping cases of "simple sore throat" had occurred before the outbreak of distinct diphtheria, and these throat cases had returned to school in various degrees of convalescence before the outbreak. In the second group, in contrast to the first, the disease had been introduced and had extended by ordinary means of personal relation, and not by school-attendance only.

6. Ely Rural Sanitary District (Cambridgeshire); population 20,702; Dr. Parsons.

Sanitary Authority: Ely R.

Ground of Inquiry: Insufficient reports of Medical Officers of Health.

Chief Facts reported: Highway drains used as sewers, badly adapted for the purpose; nuisance in ditches at outfall. House drains badly constructed and untrapped. Foul cesspit privies. Water supply in some parts insufficient; from shallow wells exposed to pollution, and from rivers and ditches which have received sewage. Houses, especially "feoffee houses," unfit for habitation. Few public improvements executed by Authority. Four Medical Officers of Health, who receive a nominal salary, and whose duties have not been satisfactorily performed.

7. Erpingham Rural Sanitary District (Norfolk); population, 17,005; Dr. D. Astley Gresswell.

Sanitary Authority: Erpingham R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Fatal prevalence of diphtheria in many widely separated parishes. Cases apparently to be traced back through personal communication, especially at schools, to some four or five cases that occurred early in 1884, and in one instance to a case that occurred in the middle of 1883. Early cases due in some instances to infection contracted from imported cases, in others possibly to "recrudescence" of diphtheria in the individual. Sanitation primitive in all the parishes where diphtheria prevailed. Systematic inspection not carried out. Nuisances allowed to remain for long periods. Privy accommodation insufficient. Privy vaults in dangerous proximity to houses and wells. Water supply of several parishes urgently demanding improvement. Cottages overcrowded; several dilapidated, and most of them requiring ventilation. No byelaws. No isolation hospital. No disinfecting apparatus.

8. Faldingworth, population, 310; and Barlings, population, 469 (Lincolnshire); Dr. D. Astley Gresswell.

Sanitary Authority: Lincoln R.

Ground of Inquiry: Enteric fever.—Registrar-General's Returns.

Chief Facts reported: Faldingworth:—Small outbreak of enteric fever traceable to pump-well water polluted by washings from a fever case imported from Newark. The well condemned, and house drains trapped since the outbreak. Water supply inadequate. Filthy ditch-sewers.

Barlings:—Outbreak of enteric fever traceable to pollution of the water supply of the village by sewage. Defective house drainage. Some vault closets in dangerous proximity to dwellings. Chief supply of water, obtained by imperfect filtering of the sewage-polluted village brook, both unwholesome and inadequate.

9. Farnham Registration District (Surrey); population, 40,395; Mr. R. D. R. Sweeting.

Sanitary Authorities: Aldershot U., Farnham U., and Farnham R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Aldershot U.—Wholesale registration of fatal throat-illness as "croup," "laryngitis," &c., from 1880 until the autumn of 1884, when it began to be generally registered as diphtheria. Extension of the disease facilitated by the tardy recognition accorded it, absence of isolation of the sick (except to a slight extent in the South Camp), and inability or unwillingness of the Sanitary Authority to deal with it. Aldershot town suffered more than the Camp, and shopkeepers in excess of others. Houses in Aldershot improperly built; many closets without proper water supply; ventilation and flushing of sewers inadequate; faulty ventilation of house drains; and faulty disposal of liquid wastes. No hospital accommodation provided by the Sanitary Authority. Disinfection only recently practised. Byelaws in need of revision.

Farnham U.—Slight endemic prevalence of fatal diphtheria since 1878, with continued prevalence of "white throat" and other infectious throat-illnesses. Several deaths recorded from "croup." Diphtheria epidemic in early part of 1882 and throughout the greater part of 1883. Numerous diphtheritic "sore throats" in the intervals between the fatal cases. Damp basements and yards; badly-arranged pit-privies and middens; badly constructed cesspools and improperly placed water-closets; foul ashpits near houses; inadequate water supply; old brick rubble drains. No main sewerage at present, but public sewers about to be provided. No isolation hospital. No regular disinfection. No notification of infectious diseases. Byelaws, based upon the Public Health Act of 1848, obsolete.

Farnham R.—Slight endemic fatal prevalence during 1875–1878, followed by a lull in 1879 and 1880. In 1881 and 1882 a few deaths from diphtheria and from "croup" registered. But in 1883 and 1884, serious epidemic fatality of diphtheria in this rural district, apparently extended to it from the urban districts of Aldershot and Farnham, especially from the former. Some of the fatal diphtheria called "croup." Extension of the disease facilitated everywhere by free personal communication between the sick and healthy, and in the parishes of Ash, Seale, and Frimley, as well as in the Bourne district of Farnham parish, by school-attendance. Pit privies of a rude kind mostly in use; a few earth-closets and water-closets. Ash heaps abundant; very few ash pits. Water usually from shallow wells, often in proximity to privies. In some parts of district rain-fall only to be depended upon for water supply. No main-drainage except that at Camberley and York Town, in Frimley parish, which is just completed. No hospital provision, except the workhouse for paupers; and this seldom used. Very little disinfection practised. No notification of infectious diseases. Byelaws are being drawn up for Frimley, which has recently been invested with urban powers.

10. Glandford Brigg Rural Sanitary District (Lincolnshire); population, 13,523; Dr. D. Astley Gresswell.

Sanitary Authority: Glandford Brigg R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Widespread outbreak of diphtheria *Ironstone Village.*—Population, 6,100. The seat of a very general prevalence of diphtheria in 1884 and first quarter of 1885, (32 deaths from diphtheria and six deaths from "croup" in 1884); the outbreak apparently traceable by personal infection to an imported case. Old-fashioned midden closets in general use, many close to inhabited buildings and to imperfectly protected shallow wells. Sewers jointed with clay, unventilated, and unprovided with means for flushing, discharge into filthy ditches near to inhabited houses. Water supply, derived from wells, both deficient in quantity and defective in quality. Schools which afforded chief means for transmission of infection, inefficiently ventilated. *Horkstow.*—Population, 274; seven deaths from diphtheria in about six weeks; cases definitely traceable, directly or indirectly, by personal infection to a case imported. No provision for isolation of infectious cases or for disinfection.

11. Gravesend (Kent); population, 23,302; Mr. Shirley F. Murphy.

Sanitary Authority: Gravesend U.

Ground of Inquiry: Information as to general insanitary condition.

Chief Facts reported: System of storing excremental filth in cesspools in proximity to inhabited dwelling houses. Pollution of foreshore by certain house drains and sewers giving rise to nuisance. Unsatisfactory method of water distribution from Gravesend Waterworks; courts and alleys without sufficient water supply. Some 50 private wells still in use as domestic water-supplies, exposed to risk of excremental pollution from cesspools. Ill-ventilated, badly constructed, and badly arranged dwelling houses, especially in lower part of town.

12. Hebden Bridge (Yorkshire); population, 5,007; Dr. D. Astley Gresswell.

Sanitary Authority: Hebden Bridge Local Board, U.

Ground of Inquiry: Enteric fever.—Registrar-General's Returns.

Chief Facts reported: Outbreak of enteric fever, brunt of which fell upon cottagers using excrementally polluted water from the "Birchcliffe stone cisterns;" other persons in far larger numbers, using the Local Board's water, having enjoyed an almost complete immunity. Very many cottages damp, dark, badly ventilated, and in particular instances overcrowded. Grave defects of house drainage. Old open middens in dangerous relation to dwellings and open watercourses. Springs numerous and largely used for domestic purposes, but in almost all cases open to pollution. No isolation hospital. No disinfecting apparatus. Byelaws obsolete.

13. Hemel-Hempstead Rural Sanitary District (Hertfordshire); population, 14,606; Mr. R. D. R. Sweeting.

Sanitary Authority: Hemel Hempstead R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Diphtheria confined in 1885 to parish of Hemel Hempstead. Thirteen deaths from throat-illness, of which seven were diphtheria. Five of the deaths in a row of damp houses, flooded at times by a canal. Deaths from "croup" in the summer; one case imported by a tramp; and cases of sore throat, preceded the fatal diphtheria. Outburst in the autumn determined by school attendance, and probably by that alone. Strong suspicion that previous "mumps" and other cases called "bad cold" had been diphtheria. Unventilated cesspits at school. No isolation provision made by Sanitary Authority. Schools not closed, but the closets cleaned and disinfected.

14. Hitchin Rural Sanitary District (Hertfordshire); population, 13,541; Mr. R. D. R. Sweeting.

Sanitary Authority: Hitchin R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Recent diphtheria confined almost entirely to village of Whitwell, in parish of St. Paul's Walden. Said to have been imported from London, but no definite evidence of this. Deaths from "croup" and diphtheria in neighbouring villages before first case at Whitwell; and minor sore throat at Whitwell before recognised diphtheria. Disease spread by personal communication and school attendance. Ventilation of a private school attended by some of the sufferers defective; unventilated cesspits at the board school which was attended by the majority of children attacked. Some disinfection carried out, and schools closed twice. No hospital provision made.

15. Kempston (Bedfordshire); population, 3,432; Mr. R. D. R. Sweeting.

Sanitary Authority: Bedford R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Seventeen deaths in 1884 from diphtheria and "croup" in a mean population of 3,567. Diphtheria mortality commenced in 1883, in sequence to major and long-continued prevalence of the disease in adjoining borough of Bedford. Chief insanitary conditions found at Kempston were dilapidated and badly built cottages, improper shallow wells, absence of drainage in a populous semi-urban part of it, and slop nuisances. Half the diphtheria attacks, and two-thirds of the deaths, occurred in the fourth quarter of 1884. Sudden increase of the disease at end of September, lasting through October and November. Relation of early cases directly with Bedford, and probably through the medium of the military barracks in Kempston. Incidence of diphtheria not determined by any special local condition, but related to age and season. Spread facilitated by unrestricted personal intercourse, and largely by school attendance; majority of

cases of school-age were attendants at a certain school, at which overcrowding occurred, where ventilation was defective, and to which, after the harvest holidays, imperfectly recovered and unrecognised cases came. Isolation of diphtheria in hospital hardly attempted. No notification of infectious diseases. No closure of schools. Energetic disinfection of rooms. Byelaws for Kempston not thoroughly enforced.

16. Kidderminster (Worcestershire); population, 24,270; Dr. Parsons.

Sanitary Authority: Kidderminster Town Council, U.

Ground of Inquiry: Local information as to recurrence of fever and leakage at lower well. [Re-inspection.]

Chief Facts reported: A recurrence of enteric fever, but to a much smaller extent than in 1884; 35 cases in second half of 1885. Cases scattered in time and locality; mostly in places where defective house drains existed. Scarlet fever prevalent in 1885.

In December 1885 a leakage of water took place from the lower well, showing that the concrete lining put in in 1884 had given way. It was not shown that sewage could have leaked into the well, nor had the occurrence any connexion with the recurrence of enteric fever.

The Town Council were engaged during the latter part of 1885 in constructing a new high level reservoir, and in reconstructing sewers, certain of the old ones being found in bad condition. They have also made considerable progress in the abatement of nuisances arising from defective privies and house drains.

17. London, districts of (Middlesex); population, 447,104; Mr. W. H. Power.

Sanitary Authorities: Hampstead, St. Pancras, and St. Marylebone Vestries: also Hendon U.

Ground of Inquiry: Scarlatina.—Information from Medical Officer of Health for St. Marylebone Parish.

Chief Facts reported: Distribution in the several sanitary districts referred to, of scarlatina along with milk from a dairy farm at Hendon. Ability of this milk to cause scarlatina, related to disease among cows at the farm.

18. Lower Sheringham (Norfolk); population, 807; Dr. Airy.

Sanitary Authority: Erpingham R.

Ground of Inquiry: Enteric fever.—Local complaint.

Chief Facts reported: Severe outbreak of typhoid fever, under circumstances pointing to contamination of milk supply. Origin of infection uncertain. Water supply from land drainage and rivulet in danger of pollution. Drainage defective. Privy accommodation insufficient. Nuisances from large privy pits, net tanning, and whelk boiling, in the village; and from ponded sewage, ordure, and fish offal, on the beach. Nuisances inspection imperfect. Need of building byelaws.

19. Mansfield Registration District, part of (Notts); population, 27,358; Dr. D. Astley Gresswell.

Sanitary Authorities: Hucknall-under-Huthwaite U., Mansfield R., and Sutton-in-Ashfield U.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Hucknall-under-Huthwaite U.—General prevalence of diphtheria, traceable through personal intercourse, especially at the National School, to a child who contracted infection in a school at Sutton-in-Ashfield. The old portion of the town abounds in unwholesome conditions: dwellings damp and badly ventilated; cramped courts and narrow streets littered with house refuse; drains defective, sewers blocked, and the ground surface very foul. The newer portion of the town in a more wholesome condition, but in need of close house-to-house inspection for detection of sanitary shortcomings. Sewers not properly ventilated, and never flushed, discharge into ditches by the roadside, and give rise to nuisance. Water supply inadequate; derived from wells, many of which are unquestionably polluted. Scavenging neglected. Many of the byelaws sanctioned in 1875 not enforced. No provision for isolation of infectious cases, no disinfecting apparatus, and no notification of infectious disease.

Mansfield R.—Epidemic prevalence of diphtheria in some parishes, and sporadic prevalence in others; traceable in most instances to infection contracted mediately or immediately from cases in either Sutton-in-Ashfield or Mansfield, the two chief market centres. The diphtheria preceded for three years by a general prevalence of sore throat apparently infectious. Population mining and agricultural. The farm labourers' dwellings of old rural type, damp, dark, ill-ventilated, and surrounded by unwholesome conditions. The colliers' dwellings built in long rows, at the back of which, and unduly near to them, are rows of ill-scavenged, uncovered middensteads; drains and sewers improperly trapped and not ventilated. Foul sewer ditches in some villages. Water supply in many villages deficient in quantity, and in several defective in quality. Schools imperfectly ventilated. No hospital for infectious diseases. No disinfecting apparatus.

Sutton-in-Ashfield U.—Very general, fatal, and sustained prevalence of diphtheria during the last three-and-a-half years: 114 deaths in 43 months. Inquired into by Dr. H. Franklin Parsons in 1882 and 1883. Ninety or more households invaded and 52 deaths during the last year-and-a-half; two-thirds of the households invaded in the persons of children attending school. The district in a most unwholesome state. Dwellings damp and ill-ventilated, and their cellars liable to filth soakage. Curtilages strewn with filth. A third of the town not sewered, another third provided with old defective rock-hewn sewers, the remaining third efficiently sewered. Old open middensteads in general use for the reception of excreta and refuse and, in parts which are not sewered, for house slops and waste water. Scavenging neglected. The brook running through the town converted into a sewer, and at times dammed up against the town, giving rise to serious nuisance. Schools defective in ventilation, infrequently cleansed, and provided in some

instances with huge deep middensteads. Water supply, drawn from wells, inadequate and open to all kinds of pollution. Byelaws not enforced. Voluntary, but imperfect, notification of infectious diseases which is paid for by S. A. No isolation hospital, and no disinfecting apparatus. Contract for public water service just let. Sewerage scheme, approved by the Local Government Board, in abeyance, borrowing powers being exhausted.

20. Market Weighton (Yorkshire); population, 1,881; Mr. Arnold Royle, C.B.

Sanitary Authority: Pocklington R.

Ground of Inquiry: Enteric fever.—Local complaint and reports of Medical Officer of Health.

Chief Facts reported: Prevalence of enteric fever in connexion with the use of drinking water from surface wells sunk in a porous soil, and contaminated by soakage from defective sewers, cesspools, &c. Faulty means of house drainage and excrement disposal.

21. Motcombe, population, 1,411; Cann, population, 560; Melbury, population, 328 (Dorset); Dr. Simpson.

Sanitary Authority: Shaftesbury R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Water supply impure and insufficient. Nuisances very general, arising from pigstyes, privies, accumulations of filth, and the improper disposal of slop water. Houses in a very dilapidated state. Dairy farms in an insanitary condition.

22. Newark (Notts); population, 14,018; Dr. Parsons.

Sanitary Authority: Newark Town Council, U.

Ground of Inquiry: Enteric fever.—Reports of Medical Officer of Health.

Chief Facts reported: Enteric fever prevalent in 1884. Somewhat high general and infant mortality. An old and closely-built town. Houses without sufficient ventilation and external space. Sewers mostly unventilated; sewage discharged into the River Trent, without purification. House drains commonly with loose iron traps, permitting escape of drain air in and near houses. Offensive midden-privies, but undergoing conversion into W.C.s and tub-closets. Insufficient closet provision. Accumulations of house refuse. Company's water supply derived from gravel bed in neighbourhood of River Trent. Shallow wells also in use, liable to contamination.

23. Nocton Rise Farm House (Lincolnshire); Dr. D. Astley Gresswell.

Sanitary Authority: Lincoln R.

Ground of Inquiry: Request of the Marquis of Ripon.

Chief Facts reported: The house half old, half new. Floor of one of the old rooms damp and mouldy. House liable to be invaded by cesspool gases. Water supply not secure against

pollution from large cesspool. Diphtheria recurrent in this farm-house since March 1881. The virus in the first instance probably imported into the house by a servant girl, and afterwards maintained there possibly in the person of one of her fellow servants, who, since her attack in 1881, has suffered repeatedly from sore throat and diphtheria.

24. Sandal Registration Sub-District (Yorkshire); population, 22,586; Mr. R. D. R. Sweeting.

Sanitary Authorities: Altofts U., Normanton U., Sandal Magna U., and Wakefield R.

Ground of Inquiry: Diphtheria, scarlet fever, and enteric fever.—Registrar-General's Returns.

Chief Facts reported: Altofts U.—Epidemic of scarlet fever in 1881, but not since. Ten deaths from diphtheria in 1884. Latter disease spread largely by schools, but also by promiscuous visiting amongst sick and healthy. Enteric fever prevalence associated with drain, ditch, and pigstye nuisances. Large, open, unventilated midden-privies draining into the public sewers. Sewers inadequately flushed and ventilated; no proper means of disposal of storm-water, which accordingly floods the sewage farm. The water supplied by the Wakefield Borough open to suspicion. No disinfection practised. No hospital provision. No notification of infectious sickness. No scavenging done by the Authority.

Normanton U.—Prevalence of fatal scarlet fever since 1879; epidemics of this fever in 1881 and 1884. Attack and fatality determined by age; spread facilitated by unrestrained intercourse of healthy and sick in the complete absence of any isolation, and aided by school-influence. Fatal diphtheria appeared in 1882, and was epidemic in 1883 and 1884. Spread by direct infection in various ways, but chiefly by school-attendance. Enteric fever prevailed during last five years, and was associated with defects of drainage. General insanitary conditions such as foul, unroofed, and badly-constructed midden-privies; continued use of wells and rain-water tanks; and inefficient flushing and ventilation of drains and sewers. No scavenging practised by the Authority. No regular disinfection. No hospital provision. Obsolete byelaws. Voluntary notification of infectious diseases in force.

Sandal Magna U.—Free from fatal infectious disease since 1882, when 10 deaths from scarlet fever took place. In 1884 a few non-fatal cases of scarlet fever, which derived infection from Wakefield; some isolated attacks of diphtheria; and a few cases of enteric fever. Drainage of Belle Vue imperfect, but a new scheme in course of being carried out. Midden-privies mostly roofed and ventilated, though sunk usually below ground level. Scavenging undertaken by the Sanitary Authority. Workhouse hospital used for isolation of infectious disease. No notification of infectious diseases in force.

Wakefield R. ("*Sandal Division.*")—Three deaths from scarlet fever, six from diphtheria, and three from enteric fever during 1884. Scarlet fever incidence and spread determined by intercommunication of healthy and sick; that of diphtheria by school-attendance; and that of enteric fever

found to have been associated with defects of drainage, as well as with cesspool and pigstye nuisances. Excrement and refuse disposal by filthy middens, and irregularly scavenged cesspools. Water supply largely from private wells, but also from surface springs and reservoirs liable to contamination. No disinfection practised and no notification of disease in this division of the Rural Sanitary District. Workhouse hospital sometimes utilised to receive urgent cases of infectious disease. Urban powers under section 44 of the Public Health Act, 1875, in force in some parts.

25. Seend Parish (Wilts); population, 919; Mr. R. D. R. Sweeting.

Sanitary Authority: Melksham R.

Ground of Inquiry: Reports of Medical Officer of Health.

Chief Facts reported: Main part of Seend village supplied from wells in the Lower Green-sand; outlying parts from shallow wells and surface springs. Supply of Sells Green (*a*) rain water; (*b*) shallow disused wells; (*c*) a spring issuing at the foot of the Lower Green-sand and Calcareous Grit. The spring about a quarter of a mile from the chief cluster of houses; it issues here as a roadside stream, and is used by all the inhabitants; its condition very objectionable. Martin's Slade hamlet derives its water supply from the Kennet and Avon Canal, from shallow wells fed probably by this canal, from unfiltered rain water, and from contaminated surface springs. Diarrhœa and dysentery rife here. Though the Trowbridge Water Company's mains extend to within three miles of the furthest point of Seend parish, no steps have been taken by the Rural Authority to obtain a good water supply for the parish. Recently a decision of the Seend Parochial Committee to do nothing in the matter was upheld by the S. A.

26. Shaftesbury (Dorset); Population, 2,312; Dr. Simpson.

Sanitary Authority: Shaftesbury U.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Diphtheria spread by infection. Drainage defective. Want of a proper disposal of sewage. Nuisances from pigstyes and privies. High death-rate. Many houses dilapidated and damp, with insanitary surroundings.

27. Shepton Mallet Rural Sanitary District (Somerset); population, 10,457; Dr. D. Astley Gresswell.

Sanitary Authority: Shepton Mallet R.

Ground of Inquiry: Diphtheria.—Reports of Medical Officer of Health.

Chief Facts reported: Outbreak of diphtheria confined to three small villages (Oakhill, Neighbourne, and Gurneyslade) on the north slopes of the Mendip Hills. Traceable to a lad who introduced it, probably from an outlying district, into his own family; whence, while still unrecognised, it spread by personal communication to three other families in his immediate neighbourhood, and through them, chiefly owing to school attendance in Oakhill, to the others who suffered. Spread through each household, largely owing to want of precautionary

measures, to defective ventilation, and to overcrowding. Schools at Oakhill imperfectly ventilated, and their water-closets, as also all other water-closets in Oakhill and the sewers into which they discharge, defective in regard of means of ventilation and flushing. Nuisances from ill-placed privy pits and accumulations of refuse. Some water supplies open to pollution. Cottages badly ventilated and damp. Settling pits for sewage at Oakhill too near to dwellings and to National School.

28. Tottenham Urban Sanitary District (Middlesex); population, 46,456; Mr. R. D. R. Sweeting.

Sanitary Authority: Tottenham Local Board, U.

Ground of Inquiry: Diphtheria and enteric fever.—Local complaints and Registrar-General's Returns.

Chief Facts reported: Rapid increase in population; high birth-rate; migratory character of population. Zymotic death-rate above the average; "Fever" rate uniformly high since 1874, as also diphtheria rate since 1881. This endemic prevalence of enteric fever and diphtheria found associated with various insanitary conditions, viz., irregular and inadequate sewer ventilation, imperfect sewer flushing, contaminated water cisterns, defective house drainage (especially in the case of enteric fever, less so in that of diphtheria), inadequate provision of ashpits, unsystematic scavenging, dampness of basements and yards, and in some parts a foul condition of the Moselle Brook. Diphtheria spread partly by school attendance. No non-pauper hospital provision. Voluntary notification of infectious diseases recently adopted. Excellent building byelaws, and vigorous supervision of new buildings.

29. Ure River (Yorkshire); population of sanitary districts visited, 50,229; Mr. R. D. R. Sweeting.

Sanitary Authorities: Aysgarth R., Bedale R., Great Ouseburn R., Leyburn R., Masham U., Ripon U., and Ripon R.

Ground of Inquiry: To ascertain the relation of the river Ure to the drainage and water supply of places on its banks.

Chief Facts reported: Eleven places found to drain directly into the Ure, of which Ripon and Masham are the chief. Many others drain indirectly into it, but in most cases by means of tributary becks, with long and roundabout courses. River distinctly polluted at eight places, especially Masham, Ripon, and Boroughbridge. Ripon the only place taking its public water supply directly from the Ure, but the intake a mile above the Ripon sewage outfalls. Shallow wells of Boroughbridge liable to flooding by the Ure and its important tributary, the Tutt, which receives most of the drainage of this town. York water supply from the Ouse, a continuation of the Ure, 15 miles below Boroughbridge and 23 miles below Ripon.

30. Walsingham Rural Sanitary District (Norfolk); population, 16,898; Dr. D. Astley Gresswell.

Sanitary Authority: Walsingham R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief facts reported: Fatal and widespread epidemic of diphtheria. Cases traceable through personal communication, chiefly in schools, to a few persons, of whom some were attacked early in 1884, and one was attacked late in 1883. These earlier cases due apparently to infection contracted in outlying districts. Sanitary condition primitive in all the parishes where diphtheria prevailed. Systematic inspection not carried out. Abatement of nuisances not enforced. Insufficient privy accommodation; privy vaults in close relation to houses and wells. Labourers' cottages overcrowded, several dilapidated, and most of them requiring ventilation. No byelaws. No isolation hospital. No disinfecting apparatus.

31. Watford Urban Sanitary District (Hertfordshire); population, 10,073; Mr. R. D. R. Sweeting.

Sanitary Authority: Watford Local Board, U.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief facts reported: Average of three diphtheria deaths per annum for eight years previous to 1885: in that year 28 deaths from diphtheria, and 8 from other throat affections. Though no cases of diptheria were recognised between January and June, many mild and slight cases of minor sore throat occurred during that period. Sudden increase of diphtheria cases and deaths in third quarter, and sustained and high prevalence of both in fourth quarter. Local insanitary conditions seemingly without special influence on the throat-malady. Disease kept up and spread by personal communication between the healthy and sick, and by school-attendance. Many absentees from the various schools during the year with "mumps," "bad cold," &c.; some of these cases examined and found to be essentially diphtheria. One school particularly implicated; some overcrowding here, and lack of through ventilation. No attempt at isolation. No proper disinfection. No school closure.

32. Wellington (Somerset); population, 6,360; Dr. Simpson.

Sanitary Authority: Wellington U.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief facts reported: Diphtheria spread by infection, confined chiefly to persons employed in factories and brickworks; incident upon houses the condition and surroundings of which were unsatisfactory. Drainage defective. Water supply from wells liable to contamination. Houses in certain portions of the town in a dilapidated and insanitary condition.

33. Wellington Rural Sanitary District (Somerset); population) 11,120; Dr. Simpson.

Sanitary Authority: Wellington R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Diphtheria spread by infection. Houses in which fatal cases of diphtheria occurred found to be defective in drainage or water supply, and in a generally insanitary condition.

34. Whixley Registration Sub-District (Yorkshire); population, 3,778; Mr. R. D. R. Sweeting.

Sanitary Authority: Great Ouseburn R.

Ground of Inquiry: Diphtheria.—Registrar-General's Returns.

Chief Facts reported: Fourteen diphtheria deaths in the Whixley sub-district during 1884, of which nine were in Whixley parish, one at Green Hammerton; other four either related to diphtheria in these two places, or from diphtheria contracted outside the district. Diphtheria occurred at end of 1883 in two contiguous houses at Green Hammerton, involving 11 persons and causing 4 deaths. Its origin obscure; no definite connexion with diphtheria elsewhere. The disease spread to a few other persons in Green Hammerton at the beginning of 1884, and was also introduced into Whixley by means of children from Green Hammerton attending Whixley School; 41 attacks and 9 deaths at Whixley in 1884, the greater number between the ages of 3 and 15 years. Incidence seemingly not related to any special local condition, except in the case of houses subject to repeated attacks, where excessive conditions of dampness prevailed. Severity and fatality dependent on age and season (autumn and winter). Spread determined by personal communication of various kinds, and largely by assemblage at school: this showed its maximum influence in the autumn, after the harvest holidays, and was perhaps assisted by the foul condition of the school latrines. Schools closed by order of the Sanitary Authority. No hospital provision made. No disinfection practised.

No. 6.

On the Relation of the River Ure to the Drainage and Water Supply of Ripon and other Places on its Banks; by Mr. R. D. R. Sweeting.

This report has reference to the general sanitary condition of a number of districts on the River Ure, in Yorkshire. Chief importance has centred around Ripon, as this city was reported to drain into the Ure, and also to take its water supply from that river; but the circumstances of the Ure were also seen to have concern for the city of York, since the water supply of that place is from the Ouse, which is formed by the confluence of the Ure and Swale a short distance below Boroughbridge, and about 14 miles above York.

Ground of inquiry.

The Ure rises on the northern borders of the North Riding of Yorkshire from the western slope of Great Shunnor Fell, by the confluence of numerous streamlets which descend from the Millstone Grit of this mountainous region. Its course is, first, for a short distance southernly, but from Hawes it proceeds due east to Wensley, through the picturesque valley indifferently termed Wensleydale, Yoredale, or Uredale. Leaving Wensley, it begins to reassume a direction towards the south, and this becomes pronounced as it wends its way through the Bedale Rural and Masham Urban Sanitary Districts. Below Masham, the Ure winds eastward to Mickley, and northward to West Tanfield. Thenceforward, it meanders south and east to Ripon, and thence to Boroughbridge, a couple of miles below which town it is joined by the Swale, and becomes the Ouse. During its course, it is joined and supplemented by numerous streamlets of various size; some of these will be referred to more particularly hereafter. The bed of the Ure is formed of irregular layers of boulders and gravel, which are nearly always exposed in the summer months, owing to the small depth of the water at this season; the river is, however, liable to flood its banks after heavy rains, especially in winter, Trout and other fish abound in the Ure and its tributary streamlets.

River Ure.

With a view to investigation of the relation, as regards sewerage and water supply, of the River Ure to populous places on its banks, from its source to its junction with the Swale at Boroughbridge, the following seven Sanitary Districts have been visited:—Aysgarth Rural, Leyburn Rural, Bedale Rural, Masham Urban, Ripon Rural, Ripon Urban, and Great Ouseburn Rural. In these, the sanitary circumstances of some 40 aggregations of population have been examined with a special reference in each instance to matters relating to drainage and water supply; and note has been made of the ability of each place to exercise harmful influence on the River Ure, as well as of the potency for mischief of that river, as a source of water supply, with reference to all or any of them. For convenience, the several Sanitary Districts will be dealt with in this Report in the order of their sequence from the source of the Ure to its junction with the Swale: and particulars as to water supply and as to drainage relations with the Ure (or with becks and streamlets tributary thereto) will be recorded concerning each of the various places visited. A brief statement will be afforded of the chief facts observed in each Sanitary District of the series, and the Report will close with a summary of the evidence collected, in its bearing on the matters which have led to the institution of the inquiry.

Places visited.

Plan of report.

(A.)—*Aysgarth Rural Sanitary District.*

The following populous places in the Aysgarth Rural Sanitary District are related to the Ure:—Hawes, Gayle, Bainbridge, Askrigg, Aysgarth, and West Burton.

Hawes and *Gayle* (population 1,890) may be taken together, as they both have relation to the same stream, viz., the Gayle or Duerly Beck, which rises from the hills above Gayle village to join the Ure half a mile below Hawes. *Water supply.*—This is mostly from springs, though also from wells. Some of the springs are covered-in "dip-wells," others are "spouts"; all of them issue from the limestone hills. The water of these springs is said to be good, though rather hard, but at Hawes the supply must be regarded as inadequate in quantity, since the springs are too few and far between in the vicinity of the place, and wells are not numerous. *Drainage.*—Within the last three years, a new sewerage scheme has been carried out at Hawes, properly constructed "sanitary pipes" having been laid down. This was effected in consequence of the prevalence of enteric fever, which maintained itself until after the completion of the scheme. Adequate flushing of the new sewers has since been provided by the placing of an automatic flushing chamber at the summit of the system. Ventilation of these sewers, however, is at present only by untrapped road gullies. The sewage is received in settling tanks prior to irrigation, the effluent flowing into a ditch which joins the Ure. At Gayle, old brick rubble drains carry away slop water to the Gayle Beck.—*Land drainage and river conditions.*—As has been said, the Gayle or Duerly Beck descends from above Gayle, and it passes through the centre of this place and of Hawes to join the River Ure about half a mile below the latter. The Beck water is stated not to be partaken of by the inhabitants of either place, but it receives much house refuse, garbage, ashes, and some slops from both Gayle and Hawes in its passage through them. The Ure, at the point of junction with it of the Gayle Beck, appeared more turbid than elsewhere, in this part of its course.

Bainbridge (population 250) is situated a mile south-west of Askrigg and a few hundred yards south of the Ure. *Water supply* is from springs in the mountain limestone, and is delivered directly to standpipes and to a few taps, which are situated on the village green within easy access of the inhabitants. *Drainage.*—This has lately been partly remodelled by the laying of 6 and 9-inch "sanitary" pipes in the place of old brick and stone rubble drains; but many of these old drains still exist, with stagnant contents and defective covering. Flushing is carried out by surface and storm water only. At the date of my visit, which was during the hot weather, the old drains emitted foul odours. There is no system of ventilation of the Bainbridge sewers except through gullies on the roadside. Bainbridge has two outlets for its sewage, both of them to the adjacent River Bain, a tributary of the Ure. Neither outlet was discharging at my visit, partly owing no doubt to the stagnation and deposition of the contents of the imperfectly constructed drains. *Land drainage and river conditions.*—The River Bain, which receives the overflow of Lake Semmerwater, descends from this lake in a north-easterly direction to Bainbridge, passes by the side of the village, and joins the Ure a quarter of a mile off. Besides the two direct drainage outlets into it, mentioned above, the Bain receives house refuse and slops which are thrown into it from yards and gardens on its banks.

Askrigg (population 624) is situated on the sides and slopes of a considerable eminence a few hundred yards north of the River Ure.

Water supply.—Water is piped from a Millstone Grit hill, a few miles distant from the town and south of the River Ure, across the river bed to a cemented reservoir, capable of holding 3,000 gallons, placed on rising ground above the town. From this it descends by gravitation to standpipes and to a few private taps. *Drainage.*—Owing to a repetition of outbreaks of enteric fever, the stone "box-drains" which formerly existed have been replaced by pipes of better construction. Flushing is effected both by surface and storm water, and also by surplus water from the reservoir. Ventilation is mostly by road gullies, but recently four 2-inch vertical upcast shafts have been put up alongside houses in the main street, and it is contemplated to carry out further this system of sewer ventilation. Sewage is received in two large tanks, which are constructed of loosely-placed Grit stones, and one of which is not bottomed. One of the tanks overflows to the Cogill Beck, which joins the River Ure, and the contents of the other soak away into land adjoining the river, and thence probably into the river itself. *Land drainage and river conditions.*—The Ure at Askrigg is joined by the Cogill Beck south of the town. This beck arises in Stag Fell, from three to four miles distant, and proceeds in a south-easterly direction to Askrigg, where it bends south to its junction with the river. Just before its junction, it receives the overflow from the large cesspool above mentioned. Besides the Cogill Beck, there is another unnamed stream which runs parallel to it through the centre of Askrigg, receiving house refuse (solid as well as liquid) on its way, and joins the Ure about three-quarters of a mile below the junction of the Cogill Beck.

Aysgarth (population 370) consists of a "Village" situated on an eminence from a quarter to half a mile south of the river, with scattered houses between it and the river. *Water supply.*—Water is partly obtained from open springs in the fields, which are liable to pollution from cow manure, and partly from pipes which convey the water of other springs from the hills. *Drainage* is by old rubble and "box-drains," which are flushed only by surface and storm water, and are ventilated solely through road gullies. The greater part of the Aysgarth drainage goes to a small beck, the so-called Aysgarth Beck, which empties itself into the Ure east of the place, and above the Lower Fall. Some isolated mansions and terraces drain to cesspools, the overflows from which eventually reach the same river.

West Burton (population from 300 to 400) is situated on the Walden Beck about a mile south of the junction of the combined Walden and Bishopdale Beck with the Ure. *Water supply.*—The three public pumps existing here were all out of order at the date of my visit and not in use, water being obtained from shallow wells, open springs, and also directly from the beck in its course through the village. *Drainage.*—This is carried out mostly by brick and stone "box-drains," though in the purlieus of several better class houses, pipes of more modern construction have been laid. A settling tank situated near the beck receives the drainage, and has an overflow to the beck. *Land drainage and river conditions.*—The West Burton or Walden Beck which arises in the hills to the southward, becomes a considerable stream before it joins the Bishopdale Beck a mile below West Burton. It receives, as before-said, the overflow from the tank accumulating the West Burton drainage, and also much liquid house refuse. Some of the inhabitants use its water for drinking purposes.

Summary of Aysgarth R. S. D.

Thus the Ure flows through the Aysgarth Rural Sanitary District for rather more than 10 miles of its length. Its velocity is accelerated by reason of the numerous "forces" and "falls" which exist in this part; and several of these which join it laterally materially increase its volume.

None of the places mentioned drain directly into it, but drainage from all the places enumerated reaches it indirectly by means of tributary becks or cesspool overflows. The only place at which the Ure in its course through the Aysgarth District is obviously fouled by sewage is at the junction with it of the Gayle Beck a short distance below Hawes. The West Burton Beck is the only stream that supplies any water for drinking purposes in this district.

(B.)—*Leyburn Rural Sanitary District.*

Leyburn R.S.D.

The following towns and villages in the Leyburn Rural Sanitary District have relation with the Ure, viz. :—Wensley, Leyburn, Harmby, Spennithorne, and Middleham.

Wensley (population 322) is situated immediately on the north bank of the Ure. *Water supply.*—This is obtained from two public pumps drawing from deep wells sunk in the gravel of the Ure, and from an open spring in the village. *Drainage.*—The greater part of Wensley is undrained ; but lately some 10 houses have been provided with drainage, "sanitary" pipes having been provided by the Authority, and the work performed by the private owner. The outlet of this drainage is directly to the River Ure at Wensley Bridge. *Land drainage and river conditions.*—Besides the direct drainage of some of the houses at Wensley to the Ure, the Wensley Beck, which descends from the hills to the north of the village to join the Ure a little below the bridge, receives the contents of several private water-closets, as well as lead washings from a smelting mill. The water of the beck was very dirty-looking and foul on the occasion of my visit to Wensley.

Leyburn (population 972) is situated on high ground, at the edge of a limestone scar, about one mile due north of the Ure. *Water supply* is from limestone springs, which are piped to a large storage reservoir capable of containing about 50,000 gallons. From this, the water is delivered to private taps and public standpipes. *Drainage.*—Stone "box-drains" exist throughout Leyburn. The imperfection of their structure and laying is evidenced in the condition of street and yard gullies, which were found almost universally blocked, their contents being consequently foul and stagnant. No ventilation is provided, except by untrapped street gullies; and there is no flushing of them except by surface water. These defects are compensated to some extent, however, by the high position of the town above river-level, and the good fall that main drains necessarily acquire in their descent to the outfall. The outlet of the Leyburn drainage is to the Hetton Beck, which joins the Ure between Wensley and Spennithorne. Some 20 water-closets drain into the Leyburn main drains, and the overflows from several cesspools reach Hetton Beck, and through it the Ure. Besides the Hetton Beck, a local stream flowing through the north-east of the town to join the Harmby Beck (to be hereafter mentioned) receives on its way house refuse and garbage.

Harmby (population 182) is placed on a hill south-east of Leyburn, and three-quarters of a mile north of the River Ure. *Water supply.*—Four public springs and other private ones supply the 30 or 40 houses constituting the village of Harmby. Two of the public springs are situated in by-lanes at lower level than the main road, and are liable to have surface matters swept into them during rains. Of the remaining two, one is placed a few yards from the Harmby Beck, by which it is liable to be flooded; and the other, though affording apparently excellent water, is situated inside a grove of trees, and is not easily accessible. Several private houses have springs in their cellars. *Drainage.*—Most of the cottages are drained by stone and brick drains to a roadside

channel, which is only partly covered and the sides of which are rudely constructed of stone slabs. Its outlet is directly to Harmby Beck, which unites with the Ure. In addition, the slops from a group of nine cottages are thrown down external gullies, the pipes from which discharge into the same beck It is thus seen that Harmby Beck gets polluted both by Leyburn and Harmby; it joins the Ure from a half to three-quarters of a mile south of the latter place, and nearly opposite Middleham.

Spennithorne (population 198) is placed on the slope of a hill about three-quarters of a mile from Harmby, and a similar distance north of the Ure. *Water* is obtained from springs, some of which are open while others are led to stand pipes. There are but few of these latter, and the open springs are difficult of access to the majority of the villagers. *Drainage* is by brick and stone drains leading mostly to cesspools, which are seldom emptied, and the contents of which either soak away into the ground, or overflow to a small separate local stream, which indirectly unites with the Ure. Some of the cottages in the centre of the village drain into another and larger beck, which joins the Harmby Beck just before its union with the Ure. This larger beck receives also from the above-named cottages and other dwellings in Spennithorne an abundance of every kind of domestic refuse and filth.

Middleham (population 818) is situated on a gentle slope less than half a mile south of the Ure. *Water supply.*—This is chiefly from shallow surface wells, but also from deep wells sunk in the Limestone; many of the public wells have run dry, and private wells are often so placed with respect to middens as to be liable to pollution by them. Water is also obtained from a running stream in a field, which is pastured by cows, and therefore liable to manurial nuisance, and from a spring situate near the stream which receives the town drainage. The Leyburn Rural Sanitary Authority have in contemplation the piping of water from an abundant spring two or three miles distant, but up to the present no progress has been made with the scheme, there having been some difficulty in negociating with the owners of the land to be traversed by the pipes. *Drainage.*—This is carried out by old stone drains, which are flushed by surface water, and ventilated by street gullies. A small part of the sewage is diverted to a field, where it soaks away; and the rest goes to a stream partly culverted and partly open, which traverses the town to join the Ure, half a mile distant. The beck which receives the town drainage receives in its passage through the place no inconsiderable amount of surface impurity and house refuse.

It is doubtful whether the considerable stream called the River Cover, which joins the Ure a mile or more east of Middleham, receives any drainage whatever from this or any other populous places.

Summary of Leyburn R. S. D.

The extent of the River Ure which flows through the Leyburn Rural Sanitary District is from eight to ten miles. It flows with a tolerably rapid velocity; its volume, which is dependent for the most part upon the rainfall, was small at the time of my visit, causing the bed of the river to be exposed in many places: I learnt, however, that flooding of its banks is not unusual under certain conditions. Wensley is the only place which drains directly into it, the drainage from the other places named reaching the river in an indirect manner. The river is manifestly polluted at Wensley Bridge, where a not inconsiderable amount of house drainage enters it; and at the point of junction with it of the Wensley Beck. No populations in this district take water directly from the river or tributary streams for drinking purposes; but the deep wells at Wensley which are sunk in the Ure gravel may perhaps be affected by the quality of the river water.

App. A. No. 6.

On the Drainage and Water Supply of Ripon, &c.; by Mr. Sweeting.

(C.)—*Bedale Rural Sanitary District.*

Bedale R. S. D.

The only considerable place in this Rural Sanitary District which has relation with the river Ure is Clifton Castle. Bedale town itself is some distance from the Ure, and the overflow from the subsidence tank into which its drainage is received passes into the Bedale Beck, and thence to the River Swale in another watershed.

Clifton Castle is a private residence containing altogether between 30 and 40 people, situated on the northern bank of a loop of the Ure. *Water* is obtained from an open spring in the fields, which is led to a reservoir, and thence to taps in the house. Some water is also pumped from the Ure for washing purposes. *Drainage.*—Clifton Castle contains altogether seven water-closets, the contents of which, together with surface water and the waste of baths and sinks, are discharged into a large iron tank which overflows to a ditch. This ditch receives also the drainage of Clifton Farmhouse (attached to the Castle), of the bailiff's house and butcher's shop, and the overflow also from a horse pond; it runs southwards from the Castle, and parallel to the Ure for some few hundred yards, and then bends to the west to join it. It presented a very unclean and turbid appearance on the occasion of my visit.

Summary of Bedale R. S. D.

Only a few (two or three) miles of the extent of the Ure is included in the Bedale Rural Sanitary District. Its flow and volume are much the same as in the Leyburn District. Clifton Castle drains indirectly to the river, and takes some water from it, but not for drinking purposes. The ditch which receives the drainage of the Castle is very foul in the neighbourhood of that mansion, but has by the time it joins the Ure become less turbid.

(D.)—*Masham Urban Sanitary District.*

Masham U. S. D.

The places in this Urban Sanitary District which are related to the Ure are the following:—Low Ellington, the several Burtons, Northcote, Aldburgh, Nutwithcote, Swinton, and Masham.

Low Ellington.—This is a small hamlet half a mile west of the Ure, consisting of two farmhouses and about eight cottages. *Water supply.*—From springs issuing from hills above the hamlet; uncovered wells in the fields, liable to contamination by manure; and shallow pump wells placed near to and on a lower level than foul liquid middens. *Drainage.*—Some of the Ellington dwellings are unprovided with drains, and slops are thrown by hand into a beck which runs through the green in the centre of the village. The contents of the stone drains from other dwellings empty themselves directly into this beck, which was found to be turbid, and foul smelling; its bed also was silted.

Burtons.—These consist of a private residence, a farmhouse, and a group of some half dozen cottages. *Water supply.*—Chiefly from deep wells, which in the case of the farmhouse is in need of protection from surface percolations. *Drainage* is carried out for the most part by "sanitary" pipes to cesspools, which are seldom cleared and overflow to the fields, where they soak away into the soil, and ultimately into the River Ure. At the farmhouse, slops enter into a ditch which joins a mill-race, and through it the Ure; this ditch also takes the overflow from a foul duck-pond.

Northcote is a small hamlet which contains the Masham railway station, four small cottages, and a farmhouse. *Water* is obtained from springs and shallow wells. The *drainage* outlet leads to a ditch emptying into a one-foot sewer, which after a short run discharges into the River Ure opposite Masham.

Aldburgh, situated on the east bank of the Ure, consists of a private mansion (The Hall) and a few cottages. *Water* is obtained from open springs and a deep well. *Drainage* products, inclusive of the contents of two water-closets at the Hall, pass directly to the River Ure.

Nutwithcote hamlet, situated a few hundred feet from the Ure, and immediately opposite Aldburgh, contains a large farmhouse and several inhabited outbuildings attached thereto. *Water supply* is from a bricked and covered tank which collects spring water in a field overlooking the house, and delivers it to taps and standpipes about the house and its outbuildings. *Drainage* is carried out by stone drains of imperfect construction, discharging into an open ditch, which joins the River Ure. It is to be noted that the river is turbid where it is joined by this ditch, and that plants on its banks at the point of junction are covered with black, dry, sewage material.

Swinton (population 100) is situated a quarter of a mile from the River Burn, which unites with the Ure about a mile below this place. *Water supply* is mostly from springs issuing from the hills which abound here, and also from deep wells. *Drainage* is received into a large settling tank, the overflow of which goes to the River Burn. This river receives also slops and solid house refuse from two small villages, Healey and Fearby, situated two to three miles west of Swinton.

The town of *Masham*, which gives its name to the Urban Sanitary District, is placed on an eminence abutting on the Ure, the centre of the town being less than a quarter of a mile from the river. It has a population of about 1,070. *Water supply.*—This is partly by a public water service, but chiefly from wells, shallow and deep, the latter being sunk into the Red Sandstone. The waterworks are due to the enterprise of a private individual, and are situated between Masham and Low Ellington, about a mile from the former. Water from springs more than two miles distant is led to the works, from which it is pumped by a water wheel along two-inch mains to an elevated service reservoir in Masham, capable of holding between 400 and 500 gallons; from this it descends by gravitation to taps and to a few standpipes. Only 65 of the 300 odd houses in Masham take water from these works; and a separate contract is required by the proprietor of the waterworks with each owner who agrees to take the water. As a rule, cottages below 10*l.* pay 6*s.* 6*d.* a year for it; houses rated at 10*l.* pay 2*d.* a week, and those rated above 10*l.* pay 1*s.* in the £. Up to the present, the Masham Urban Sanitary Authority, though strongly advised thereto by Dr. Horsfall, the Medical Officer of Health, have not acquired these waterworks, chiefly, I am told, on account of the high price demanded for them. *Drainage.*—The drainage of Masham is undergoing gradual remodelling. Formerly old "box-drains" existed throughout the place; but at present only the main sewer is of this character, branch drains being all glazed earthenware pipes. Flushing of the main sewer is effected by diverting the "Swinny Beck" into it, but this can be done only by permission of a private owner, through whose property the stream flows. Sewer ventilation is effected only by untrapped gullies in the streets. About 20 water-closets exist in the town, and they all drain to the sewer. It is the rule for sink and other waste pipes to be disconnected from the drain, and for yard gullies to be trapped, though exceptions to this are to be met with. The sewers of Masham have three outlets, (1) a "south-west" outlet to the "Swinny Beck" (south of the point where it is used for flushing purposes) which joins the River Burn half a mile above the junction of the latter with the Ure; (2) a "central" or the "Scarbeck-Wall" outlet, to a ditch which forthwith discharges in the Ure; and (3) a "north" outlet, directly to the same river.

The Ure at Masham is distinctly polluted by the sewage of the town. The ditch which conveys sewage from the "central" outlet to the river is especially foul in appearance and smell; its beds and sides are silted up, too, by dark purplish material. The river here is turbid for some distance below the "north" outlet, and below that of the above-mentioned ditch. Sewage from the "south-west" outlet, gaining access indirectly to the Ure by means of the "Swinny Beck," does not conspicuously foul the river.

The Ure traverses the Masham Urban Sanitary District for some five or six miles of its course. Its flow is sluggish, especially at Masham town, though its volume is now large and its depth increased. The low-lying land on its south bank at Masham, through which the central and northern sewage outfalls run before discharging into the river, is usually more or less flooded by the Ure during the winter season. It receives drainage matters directly from Aldburgh and Masham; and indirectly from Low Ellington, the Burtons, Northcote, Nutwithcote, Swinton, Healey, and Fearby: all of these places, with the exception of Masham, are inconsiderable in size and population. The Ure is gravely fouled at Masham, and is also turbid and discoloured at Nutwithcote. The water of the river does not appear to be at all used for drinking purposes in this Sanitary District.

(E.)—*Ripon Rural Sanitary District.*

The following are the places in the Ripon Rural Sanitary District having relation, directly or indirectly, with the River Ure, that I visited during my inquiry, viz.:—Mickley, West Tanfield, North Stainley, Wath, Melmerby, Nunwick, Sharow, Copt Hewick, Bridge Hewick, Bishopton, Laverton, Kirkby-Malzeard, Grewelthorpe, Markington, and Bishop Monkton.

Mickley (population 190) is situated on the edge of a plateau forming the south bank of the River Ure, and surface washings as well as slops, therefore, discharge directly into the river. *Water supply* is chiefly from shallow wells. *Drainage.*—There is no main drainage in Mickley, slops and house drainage from a number of dwellings finding their way to the River Ure, as before said.

West Tanfield (population about 540) abuts on the north bank of a loop of the River Ure. Its *water supply* is obtained from an excellent spring, and from deep wells in the Magnesian Limestone. *Drainage.*—Recently West Tanfield has been provided with main drainage, constructed of glazed earthenware pipes. House drains have in many parts been cut off from direct connexion with the main sewer, and have been ventilated. Some houses on the riverside, which are unprovided with ashpits, get rid of their house refuse by throwing it into the river. The sewage of the place is disposed of in a large tank, situated in a field, the overflow from which passes into a second tank containing loose charcoal, which is removed from time to time when saturated. With the exception of the house refuse referred to above, little, if any, polluting matter from West Tanfield reaches the river.

North Stainley (population about 400) is from half to three-quarters of a mile south of the river. Its *water supply* is from open springs and shallow surface wells. *Drainage.*—Old fashioned stone drains conduct slops and surface water to a tank having an overflow to a ditch, which after a course of about two miles joins the Ure. At Slenningford, a hamlet in the parish of North Stainley, slops and house refuse of all kinds are thrown into a mill-race, which also eventually joins the Ure.

Wath (population about 250) is rather more than a mile north-east of the Ure. *Water supply* is from deep wells sunk in Magnesian Limestone. *Drainage.*—The place is furnished with main drainage of a modern character, the outlet of which is to the Nunwick Beck, to be further referred to.

Melmerby (population about 300), a mile east of Wath, is two miles from the Ure. *Water* is obtained from deep wells similar to those at Wath. *Drainage* is by modern "sanitary" pipes, and house drains are ventilated by stack-pipes against the sides of the houses. The sewers discharge into a tank, which overflows to the Nunwick Beck.

The hamlet of *Nunwick* (6 houses; population 38), placed half a mile from the Ure, drains directly into the beck of the same name. This stream, which is formed by the junction of several small rivulets north-west of Wath, flows past that place and due south to Nunwick, where it bends westward again to join the Ure. As has been said, it receives on its way the drainage of Wath, that of Nunwick, and the overflow from the Melmerby sewage tanks. In its course through Nunwick, its water was found to be very dirty and turbid.

Sharow (population 380).—This parish consists of two distinct portions, a main part or "Village," rural in character, and the semi-urban "Ure Bank" portion. No part of its inhabited area is distant from the Ure more than one mile. The *water supply* of the "Village" is from 14 wells, part of them shallow, and the rest deep; and also from open springs in the fields and by the roadside. Two of the wells have recently been closed as polluted, by action of the Sanitary Authority. *Drainage* is carried out in some places by pipes of old construction, and in others by more modern "sanitary" conduits; their outlets are directly to the River Ure, about half a mile below Ripon, and about a quarter of a mile from Sharow village. The contents of many water-closets are received into this system of drainage, since better class houses abound at Sharow.

The "Ure Bank" portion of Sharow consists of 49 houses (including Ripon railway station), with a population of 189 persons. It is situated on the north-east of Ripon, being separated from it by the Ure; a field 70 yards wide intervenes between the river and the chief part of "Ure Bank," viz., the Terrace. *Water supply.*—Except some half-dozen houses which have water delivered to them from the Ripon town mains, "Ure Bank" is dependent upon shallow wells, sunk in the loose gravelly soil near the river, and liable to contamination from cesspools. *Drainage* properly does not exist in this part of Sharow. Surface water soaks into the soil, and slops are received into cesspools. Of these there are eight, of which a large one (about 164 feet cubic capacity) serves for seven houses, and the remainder for smaller groups of dwellings. These cesspools overflow into the gravelly soil in which they are placed, to the danger of wells similarly situated; and soakage from them doubtless eventually reaches the Ure. A few years ago, it was sought to connect the drainage of "Ure Bank" with that of Ripon town, but this scheme did not meet with the approval of the Ripon Corporation. Recently, an inquiry was held by one of the Board's Inspectors, Major-General Scott, as to a loan that was sought by the Ripon Rural Sanitary Authority for improving the water supply and drainage of "Ure Bank." It was proposed to pipe water from an abundant stream (Sprinkle Beck), some three miles distant, to the parish of Sharow generally and "Ure Bank" in particular; and to carry out a main drainage scheme to the latter, the sewage to be disposed of by passing it through filtration tanks. But the water scheme was strongly opposed by the inhabitants of the main part of Sharow,

who considered the parish generally to be well off for water, and in this Major-General Scott seems to have concurred. The drainage scheme was also condemned by the Inspector, who considered the tank provision inadequate. The loan was not, therefore, sanctioned, and "Ure Bank" remains in the same state as before.

Ripon railway station, which contains several water-closets, drains directly into the Ure, just below the bridge crossing the river.

Copt Hewick (population about 220) is a mile or so from the Ure. *Water* is obtained from open springs and shallow wells. *Drainage* is, mostly, by properly constructed "sanitary" pipes, though in some isolated parts of the township ancient "box-drains" still exist. Many house drains are now ventilated. The outlet of the sewage is directly to the Ure, at a distance of rather less than a mile.

Bridge Hewick (population about 70) is half a mile from Copt Hewick and a mile from the Ure. *Water supply* is similar to that at Copt Hewick. The *drainage* outlet is also to the Ure, the Bridge Hewick outfall drain joining that from Copt Hewick; together they form a 10-inch pipe which empties its contents into the Ure about a mile below Ripon. Hereabouts the river appeared distinctly polluted for many feet below the outfall.

Bishopton (population about 100).—This small township, situated west of and close to Ripon, is a mile and a half from the Ure. It obtains its *water* from springs and shallow wells, and *drains* directly into the Laver at its junction with the River Skell, which latter joins the Ure about a mile below Ripon.

Laverton (population about 300) is also on the Laver some six miles west of its junction with the Skell. *Water* is obtained from shallow and deep wells, and some of the former, situated close to the river, are not improbably fed from it. *Drainage* is by old stone drains, which convey slops to roadside ditches, these in turn discharging into the Laver. This river is formed by the union of several small becks and gills proceeding from the moors west of Laverton, and flows in a serpentine manner to join the Skell about half a mile south-west of Ripon.

Kirkby Malzeard (population about 600) is three-quarters of a mile north of Laverton. *Water* is obtained from shallow superficial wells sunk close to middens, and also from deep wells in Millstone Grit. A few springs also exist in the place, but most of them are disused. *Drainage* is by old "box-drains," which carry surface water and slops to ditches which gain the Kex Beck, a tributary of the River Laver. This beck rises from the moors west of Kirby Malzeard, passes north of it, and then bends in a south-easterly direction to join the Laver several miles from Kirkby.

Grewelthorpe (population about 500) is situated about a mile north of Kirkby Malzeard. Its *water supply* is chiefly from deep wells in the Grit. The place is *drained* partly into a pond overflowing to the Dale Beck, which joins the Kex Beck previously mentioned, and also to a ditch which after a long course joins the Ure at Hackfall.

Markington (population about 450).—This place is situated at the extreme south of the Ripon Rural Sanitary District, two and a half miles south of the Skell and a much greater distance from the Ure. *Water* is obtained from a neighbouring spring and delivered by gravitation to standpipes. The *drainage* and much house refuse of Markington gain access to a local beck, which passes at first south-east to South Stanley (in another district), and then bends north to Copgrove (also out of the district), to the east of which it joins the River Tutt, which in turn unites with the Ure eight or ten miles off at Boroughbridge.

Bishop Monkton (population about 470), situated three miles north-east of Markington and about one mile from the Ure, has an excellent supply of *water* from a Magnesian Limestone spring, which is stored in a field 300 yards away from the village and delivered to standpipes at a good pressure. There is no main *drainage*, slops and liquid house refuse finding their way through imperfectly laid stone drains, or being thrown by hand into a stream (unnamed), which passes through the centre of the village to join the River Ure rather less than a mile from Bishop Monkton.

Summary of Ripon R. S. D

The Ure has a course through the Ripon Rural Sanitary District of about 12 miles. Its flow is for the most part rapid; its volume is reinforced by springs and cascades in some parts, but is usually small in proportion to the carrying power of its bed, leading to exposure of this; flooding seldom occurs. Four places pour their drainage directly into it, viz., Mickley, Sharow, Copt Hewick, and Bridge Hewick, whilst that from the remaining eleven places referred to in this Report reaches the Ure in an indirect manner through becks and rivulets, many of which join the river a considerable distance from the point of pollution. But grave nuisance is caused by the almost universal practice of throwing solid refuse into streams. The Ure is manifestly polluted at Bridge Hewick and Sharow. The water of the river is not directly used for drinking purposes in this Rural Sanitary District; but at Laverton, and at "Ure Bank" in Sharow, the shallow wells in the neighbourhood of the river may perhaps be affected by the quality of its water.

(F.)—*Ripon Urban Sanitary District.*

Ripon U. S. D

This consists of the township of Ripon, together with Bondgate, which, though within the adjacent township of Aismunderby, is comprised within the limits of the Borough of Ripon. The Urban Sanitary District, with an area of 1,580 acres, had in 1881 a population of 7,390 persons in 1,608 houses. Its population at the middle of 1885 is estimated at 7,740.

Ripon.

The sanitary circumstances of Ripon will be described in fuller detail than those of the other places already dealt with, owing to its greater size, more important character, and more intimate relation to the River Ure.

Yards.

Condition of yards.—Most of the back yards in Ripon are badly paved and channelled. They are in consequence apt to be damp, and to retain surface filth about them, through difficulty of cleansing.

Dwellings.

Condition of dwellings.—In the older parts of the town, houses are huddled together without regard to need for circulation of air about them; outbuildings, too, and middens, which are often clustered about dwellings, contribute to stagnation of air. Some new houses bear evidence of faulty construction, and others have apparently been built upon "made ground," composed of the "tips" of rubbish and ashes. But there exist many old and substantially erected residences, which have been improved from time to time.

Water supply.

Water supply.—Ripon takes its water directly from the River Ure, 40 miles below its source. Most of the Urban Sanitary District is supplied from the public service, the chief exceptions being the hamlet of Fisher Green, where the inhabitants have recourse to an open surface spring and to the River Skell, and a house at Quarry Moor, which is dependent for water supply upon a spring nearly half a mile distant. There are also a few deep wells remaining in use in the town. The intake of the Ripon Waterworks is about 50 yards above the bridge which crosses the river north-east of the city, and just below the bathing place of the city. From this point the water is delivered by two small centrifugal pumps to three filtering beds, each of which

possesses an area of 2,400 square feet, and a depth of 8 feet, 5 feet 9 inches of which is occupied by the filtering material (sand), and the rest by the water to be filtered. The filtered water gravitates to a "well" at the pumping station, whence it is pumped by a 14 horse-power engine to the town mains, and also to a service-reservoir capable of holding 260,000 gallons, which is intended to supplement, when needful, the supply to the mains. The water is delivered from the mains chiefly to taps inside houses, but to stand-pipes in the poorer quarters. During the three years ending March 31st, 1885, the average quantity pumped daily was over 220,000 gallons, equal to about 28 gallons per head per day. The cost of pumping is said to be very high. The water rate to ordinary consumers is therefore also high, viz., 1*s.* 4*d.* in the £ upon rateable value; cottages below 5*l.* per annum being charged 6*s.* 6*d.* per annum. There are special charges to innkeepers and the like, and there is a sliding scale of charges for supply by meter, ranging from 3*l.* for 30,000 gallons in the half year, to 3*l.* 15*s.* for 200,000 gallons. It must be noted that there is a land drain outlet into the Ure only a few yards below the intake of the waterworks. The Ure water, as it is taken from the river for supplying the city, was analysed by Professor Frankland in 1874; and in 1885, two samples taken by myself on June 29th, one from the river at the intake, the other from a tap in the town, were forwarded to Dr. Dupré for analysis. The result of these analyses are subjoined.* It will be seen that

* Analysis by Professor Frankland in 1874 of the River Ure 40 miles from its source, used for supplying the City (in parts per 100,000):—

Total solid impurity	17·04	Total combined nitrogen	·038
Organic carbon	·239	Previous sewage contamination	0
Organic nitrogen	·037	Chlorine	1·20
Ammonia	·001	Hardness { temporary – 2°·5 / permanent – 9°·3 }	11°·8
Nitrogen as nitrates and nitrites	0		

Turbid: "free from any evidence of previous sewage or animal contamination."

Report by Dr. Dupré on two samples of water received on June 30th, 1885.

"No. 1 taken from River Ure as the intake of the Ripon Waterworks, obtained June 29th, 1885."

"No. 2, tap water from house in Water Skellgate, Ripon, obtained June 29th, 1885."

Both waters are soft and slightly peaty. They show no signs of sewage contamination. Sample 2, although of the same general character as 1, is in all respects slightly purer, but still yields a very minute trace of deposit containing various algæ and animalculæ, and it would be improved by filtration.

	"No. 1."	"No. 2."
Appearance	Slightly turbid	Clear.
Colour	Brown	Pale brown.
Smell	Inodorous	Inodorous.
Deposit	Slight	Very slight.
Nitrous acid		
Phosphoric acid	Minute trace	Minute trace.
Poisonous metals		
Hardness before boiling	9°·7 (Clark)	9°·5 (Clark.
„ after „	5°·5 „	5°·5 „
	Grains per Gallon.	Grains per Gallon.
Oxygen absorbed from permanganate.	0·236	0·221.
Total dry residue	13·44	12·32.
Colour of residue	Pale brown.	Pale brown.
Behaviour of residue on ignition	Blackens, but burns off readily.	Blackens, but burns off readily.
Chlorine	0·595	0·560.
Nitric acid	Trace	Trace.
Ammonia	0·00448	0·0000.
Albuminoid ammonia	0·00560	0·0036.

Professor Frankland found the water free from sewage or animal contamination, though its organic purity was not perfect. It will be perceived also that Dr. Dupré found no signs of sewage contamination in either of the samples sent him, both being soft and peaty, and that he regarded the tap-water after filtration as rather purer than the river water, since it contained, amongst other things, less solids and albuminoid ammonia and no free ammonia. It deposited, however, on settling, low forms of vegetable and animal life, viz., a variety of algæ and animalcules, such as to lead him to advise filtration as a means of improvement. But since the sample in question ("No. 2" in footnote on page 54) had already been filtered at the Ripon Waterworks, it would appear that the filtration there was not so efficient as it might have been. On June 18th of this year, a special report was presented to the Town Council of Ripon by its Water Supply Committee, which, after commenting on the costliness of the present arrangements for water supply, and the outlay that would in the future have to be expended on new pumping plant, recommended that a new supply should be obtained from certain moors by an 8-inch main, to join the present supply on the outskirts of Ripon. The estimated cost of this new scheme is 11,000*l.*, and I understand that application is shortly to be made to the Local Government Board for the Board's sanction to borrow this sum. The water from certain springs on these moors was analysed in 1874 by Professor Frankland, and found to be of a remarkable purity. *Drainage.*—A main sewerage system exists for the greater part of Ripon, the exceptions being a few outlying residences and groups of cottages, which drain to cesspools. The character of the pipes which are intended to convey away sewage from houses and streets, is undergoing gradual alteration at Ripon. Old sewers, loosely joined and covered, and not infrequently having no bottom but the soil, still form the majority, but they are being from time to time replaced in many parts by glazed earthenware pipes. In fact, a kind of piecemeal patching up of the present system has been going on since the abandonment in 1878 of Mr. Filliter's scheme for a complete renovation of the system. The course of the Ripon main sewers is irregular, their fall is often imperfect, and they are joined by many house drains at right angles. These latter are seldom provided with any proper air-break or trap in their course to the main sewers, and it is the exception for soil pipes or house drains to be ventilated; slops are either thrown down external yard gullies, which are often blocked and foul smelling, or are conducted by leaden pipes directly to the drain. But in some newly erected houses, sink and bath waste pipes are cut off from the house drains, and empty over trapped gullies. The outlets of the drainage of Ripon are to the River Ure, either directly or through the River Skell, which joins the Ure about one and a quarter mile below Ripon Bridge. The Skell receives numerous private drain outlets along its banks, and also indirectly the contents of the large Blossomgate sewer, which are poured into a mill-race joining this river. Other main sewers, too, *e.g.*, those of Westgate and Bondgate, discharge indirectly into the Skell by way of ditches and mill streams. The Ure itself receives the contents of the huge brick "Skittergate" sewer, which collects the drainage of a large part of the centre and north of the city, and is continued into a backwater at the north-east of the town, which after a course of a few hundred yards joins the Ure about a mile below the intake of the Ripon Waterworks. This backwater is practically an open continuation of the Skittergate sewer; and it is extremely foul, its bed and sides being silted up. The Ure at its junction by this backwater is turbid and discoloured for some

Drainage.

distance. The condition of the Skell must be spoken of in more detail. It approaches the city from the south, forms a loop with its convexity northwards just before entering it, and then courses through it from east to west to join the Ure about a mile and a half below the waterworks' intake. Besides polluting material from the various sewers and drains directly to the River Skell, heaps of rubbish and refuse deposited on waste land close to the confluence of the Laver and Skell are apt in flood time to be swept into the latter stream; other similar heaps are also placed on its banks lower down; and in addition, refuse-matters from varnish works, hide tanneries, and breweries pass freely into it; the drainage and liquid refuse of cow-houses also enter it. As a consequence of this disregard of the Rivers Pollution Prevention Act, 1876, the River Skell presents a very foul appearance at many points, particularly at Borrage Bridge; and the Ure where joined by it displays vegetable and oily matter on its surface, and is altogether foul. Sheep washing goes on both in the Skell, and in the Ure below the waterworks' intake.

Excrement and refuse disposal;

Excrement and refuse disposal.—This is effected in the greater part of the district by the midden privy. Water-closets are met with only in the better class houses, and their form is usually that of the "pan and container." Middens are in the majority of cases large receptacles excavated in the ground, neither roofed nor bricked at the bottom. They often receive slops and vegetable refuse, as well as rain drippings from the privy roof. Many cottages in the poorer parts of the town are unprovided with ashpits, and consequently ashes are disposed in heaps in the yards. Scavenging is contracted for by the Urban Sanitary Authority for 6*l.* a month, and

and removal.

is performed in an irregular and imperfect manner. It is not uniform in its application, and does not appear to be either universal or compulsory; people are allowed to get rid of or retain their refuse at their own pleasure. As a consequence, I met with accumulations in middens which had not been removed for many months, and masses of manure heaped against house walls. *Slaughter-houses.*—There are about 13 of these in Ripon. They are mostly drained, and duly paved and channelled. But they are not registered, and no special supervision of them is made. *Byelaws.*—The byelaws of the Urban Sanitary Authority were executed in 1864, and have not since been amended. Based as they are on the Local Government Act of 1858, with incorporated sections from the Towns Improvements Clauses Act of 1847, they must be looked upon as out of date, and in need of revision.

Summary of Ripon U. S. D.

Ripon, situated immediately on the Ure, is intimately connected with that river, both as regards its drainage and its water supply. All the sewage of the city enters the river, either directly by the backwater continuation of the Skittergate sewer, or indirectly by way of the Skell. Much house and manufacturing refuse is also poured into the latter stream. These matters include contents of numerous water-closets, belonging to houses of the well-to-do. The Ure, at the points of junction with it of these two outlets, is very much discoloured, and solid sewage material is freely deposited on its banks and in its bed. The summer volume of the Ure at Ripon is small; but its flow at that place is uniformly rapid, and there does not seem any possibility of backflow of sewage from either the outfall of the backwater, or from the junction of the Skell with the Ure. The Ripon water supply, taken directly from the Ure more than one mile above the sewage outlets, does not appear at the present time to suffer, in any marked respect, from the sanitary shortcomings of the City, or to show any serious amount of impurity which can be recognised by the chemist; but the position of

its intake is not free from objection; and there is always the danger of the entrance of specific particulate matter from places above Ripon.

(G.)—*Great Ouseburn Rural Sanitary District.*

Except Milby, Langthorpe, and Roecliffe, three small townships, the drainage of which passes directly to the River Ure, Boroughbridge is the only place of any size and importance in the Great Ouseburn Rural Sanitary District which has any intimate relation to that river. The *water supply* and *drainage* of Boroughbridge will now be briefly described, and will form the last of the series, since the Ure, from two to three miles below this place, is joined by the Swale and becomes the Ouse.

Boroughbridge abuts on the south bank of the Ure, and has a population of 950.

Water supply.—This is mostly from shallow wells, which are subject to contamination from privy percolations; and are also apt, when the Ure and Tutt are in flood, to get surface impurities washed into them. There are besides a few deep wells; and a public pump in the market place, drawing from a well in the Red Sandstone at a depth of 256 feet. *Drainage.*—This is carried out principally by old brick drains, arched over, but usually without bottoms; they have often been found blocked and silted up with deposit, and yard gullies are in consequence apt to emit noisome smells. In some parts of the town, however, "sanitary pipes" have been laid down after the occurrence of enteric fever. The outlets of the Boroughbridge drainage are indirectly to the Ure, and directly to the River Tutt or Minskip Beck which joins the Ure within the confines of the town. This rivulet proceeds from near Copgrove, and flows in a north-easterly direction to Boroughbridge, which it traverses from south to north, to its point of junction with the Ure. The Tutt roughly divides the town into eastern and western portions. Of these, the former drains to the Tutt by numerous separate drain outlets; and the latter to the Ure by way of some 400 yards' run of an 18-inch earthenware pipe discharging into a beck, which joins the Ure a mile below the town. The Tutt, as it flows through the town, and the upper waters of the beck which receives the drainage of the west of the town, are both of them turbid and fouled with slime, though the Ure at the outfall of the beck is not manifestly polluted or discoloured. Both the Ure and Tutt at Boroughbridge are liable to flooding, and sluices are placed at the beck outfall, and at several house-drain outlets along the Tutt to restrain rising of the river into the drains; nevertheless, it is said to be common enough for river water (especially that of the Tutt) to flood the town drains, and to emerge at the openings of yard gullies.

Summary of Great Ouseburn R. S. D.

The extent of the Ure which flows through the Great Ouseburn Rural Sanitary District is between five and six miles. It is of good volume throughout; but its flow is sluggish at Boroughbridge, and at this place it is very liable to flood. The drainage of the three inconsiderable townships, Milby, Roecliffe, and Langthorpe, enters the river directly, whilst that of Boroughbridge, though technically "*indirect*," must yet be regarded as closely related to the Ure, inasmuch as most of it goes to the Tutt, which flows through the midst of the town and joins the main stream within the town precincts. No water is taken directly from the Ure or Tutt for drinking purposes, but the shallow wells, which afford the chief supply of Boroughbridge, are not infrequently flooded by both rivers.

General Summary.

General summary. Direct drainage.

From the foregoing history, it is perceived that the following, of the various places in the several Sanitary Districts visited, pour their drainage *directly* into the River Ure, viz. :—

Wensley,	Copt Hewick,
Masham,	Bridge Hewick,
Aldburgh,	Langthorpe,
Mickley,	Roecliffe,
Ripon,	Boroughbridge,
Sharow,	Milby.

Of these *Masham and Ripon are the most grave offenders*, the Ure being conspicuously fouled by the drainage of these places.

Indirect drainage.

Other places mentioned as draining to the Ure do so *indirectly* by way of tributary streamlets, some of which are insignificant in size, while others, again, are of a more important character. These tributary streams have, in many cases, a long and winding course before they reach the main river, especially those in the Ripon Rural District, where the drainage of such places as Markington, Bishop Monkton, Wath, Melmerby, and Laverton gets to the Ure in a very roundabout fashion. But in some cases, notably at Boroughbridge, the tributary stream which receives the sewage unites with the Ure at or near the town ; hence Boroughbridge is included in the above list. Ripon is another instance of this, part of its drainage going to the Skell, which joins the Ure a mile below the city.

The use of the river for the disposal of ashes is common, and is certainly quite without justification.

State of river.

The River Ure showed obvious signs of pollution at the following places :—

1. Hawes (at the junction of the Gayle Beck with it).
2. Wensley (at the bridge, and at the junction with it of the Wensley Beck).
3. Masham.
4. Nutwithcote.
5. Ripon.
6. Sharow.
7. Bridge Hewick.
8. Boroughbridge (at the junction of the River Tutt with it).

Water supply from river.

Ripon is the only populous place on the Ure which takes water for drinking purposes directly from that river.—As regards tributaries of the Ure, the beck at West Burton is partly used for drinking purposes, but water is taken from it above the entrance into it of the overflow of the sewage tank. The wells of Wensley and Sharow ("Ure Bank"), which are sunk in the gravel beside the river, and those of Laverton, which are situated close to the bed of the Laver, may perhaps be regarded as liable to be affected by the quality of the river water ; and the shallow wells of Boroughbridge are without a doubt periodically flooded by the Ure and its important tributary, the Tutt.

Volume : rate of flow : flooding.

The volume and rate of flow of the Ure are variable. Volume is increased in the Aysgarth, Masham, and Great Ouseburn Districts, but is usually small in the others, especially during summer. Velocity of the stream is diminished in the Masham and Great Ouseburn Districts, increased in the others. Flooding of its banks takes place more or less constantly in the Leyburn, Bedale, Masham, and Great Ouseburn Districts, especially in the latter two.

The scope of my inquiry did not embrace the relation of populous places in the valley of the Swale to that river, nor did I have opportunity of examining the drainage and water supply of towns watered by the Ouse. But from incidental observation, I did not see any reason for concluding that these could be far different from the conditions noticed with respect to the Ure.

Conclusion.

The following considerations appear to arise from a review of the facts collected in this inquiry as to the relation of the River Ure to the drainage and water supply of places on its banks:

I. The importance to *Ripon* in the matter of water supply, of the discharge into the Ure of Ripon sewage, and of the drainage of places above Ripon.

II. The importance, as regards water supply, to populous places below Ripon, more especially *York*, of the discharge into the Ure of the drainage of Ripon and of places below that city.

(*a.*) Ripon, beyond all other populous places on the Ure, makes use of that river, and in a dual manner; for it alone takes the Ure water as its public supply, and it contributes more than all the rest put together to the pollution of that river. But the position of the waterworks' intake is above the outfall into the river of the town drainage, and more than a mile distant from it, and there is little chance of pollution by sewage. The Ripon water supply can therefore hardly be affected by the Ripon drainage.

(*b.*) The only populous places above the Ripon intake which drain directly into the Ure are:—Wensley, Aldburgh, Masham, and Mickley; and all of these have inconsiderable populations, except Masham, which is not less than 15 miles above Ripon. Mickley, the nearest tolerably populous place to Ripon directly polluting the Ure, is about 11 miles from it; and the amount of house drainage which here reaches the river is very small. The various other places above Ripon referred to as draining indirectly to the Ure do so by means of becks and streamlets, which join the main stream after a more or less long and tortuous course.

Upon the whole, therefore, having regard to the condition and physical circumstances of the River Ure in its course above Ripon, the water supply of that city may be looked upon as not being, under ordinary circumstances, largely contaminated; and though chemistry may not be able to affirm the wholesomeness of a water supply, there is nothing in the analyses in 1874 and 1885 of Professor Frankland and Dr. Dupré to lend support to an opposite conclusion with respect to Ripon water. But the position of the intake might be amended, and the filtration improved.

(*c.*) As has been said, the drainage of Ripon passes into the Ure about a mile below the city directly by way of a backwater (which is virtually an open sewer), and indirectly through the River Skell, which joins the Ure between Ripon and Boroughbridge. Below Ripon, the Ure is polluted also by the direct drainage into it of Sharow, Copt Hewick, Bridge Hewick, Langthorpe, and Roecliffe; whilst Boroughbridge pours the greater part of its drainage products into it by means of the River Tutt. By the time, then, that the Ure after passing

Ripon reaches Boroughbridge (eight miles below Ripon) it has received a much larger amount of sewage than in the whole of its previous course; and, seeing that the inhabitants of Boroughbridge drink the water of shallow wells liable to be flooded by the Ure, the uniform wholesomeness of their water supply may be seriously called in question. Upon leaving Boroughbridge, the Ure gets further polluted by the sewage of that place and of Millby.

(*d.*) York takes its water supply from the Ouse (formed by the junction of the Ure and Swale) some 15 miles below Boroughbridge. On referring to Dr. Airy's Report on enteric fever at York, I find that it is pumped from the river just outside the borough boundary, filtered through beds of sand and gravel, and distributed to the city from a reservoir. This water was analysed in 1876 by Mr. Pattinson, and, though brownish-yellow from peaty matter, was pronounced free from nitrogenous organic impurities. The Ouse has, by the time it gets to York, received not only a considerable amount of impurity that has been brought into it by the Ure above Ripon and by the Swale, but also the drainage of the city of Ripon, of five small villages, and of Boroughbridge. It also doubtless receives, before it furnishes York with its water supply, further impurities from places along its banks, after the junction of the Ure and Swale. The sum total of contamination contributed by the Ure to the Ouse is therefore great. This abundant pollution of the river from which York derives its drinking water is not indeed revealed by the analysis of the York water, appended to Dr. Airy's Report; but such contamination by fœcal matter, with the numerous opportunities so afforded for pollution of water supply by specific disease-elements, becomes a matter of grave concern for that city. It might, on some future occasion, be a source of disease, or the means of spreading imported disease. Even admitting that such misfortune is unlikely, and that when it occurs it may be hard of demonstration, and indeed against the presumptions of the chemist, it must yet be acknowledged that the risk run by York is in no wise diminished by these considerations, and is well worthy of being recognised beforehand.

No. 7.

On the Manufacture of Rag Flock in reference to the possible Dissemination of Infectious Disease by this and other Products of Woollen Rags; by H. F. Parsons, M.D.

Rag flock.

The manufacture of rag flock consists in the tearing up of rags into a fibrous material used for the stuffing of beds and articles of furniture.

The object of the present inquiry is to learn whether this manufacture involves any risk of infectious disease to persons engaged in it, or to those who use the manufactured article, and if so, how such risks may be obviated.

Any such risk, if it exist, depends upon the nature and antecedents of the rags which form the raw material of the manufacture, rather than upon the processes to which they are subjected in their conversion into flock. It will therefore be necessary to consider what these rags are, and where they come from. For the same reason:—viz., that danger of infection attaches to rags, *quâ* rags, rather than through the uses to which they are subsequently put,—it will be convenient to consider briefly at the same time from this point of view the other industries besides flock-making in which rags or their products are employed.

Cotton and linen rags are the province of the papermaker, and I need not here describe the processes of manufacture to which they are subjected, as I have already treated of these and the attendant dangers to the health of the workpeople in a report published as an appendix to the Annual Report of the Medical Officer of the Local Government Board for 1881.

In the present report I shall therefore treat of the risks of infection attaching to the use of woollen and partly-woollen rags in the various industries in which they are employed.*

The rag trade.

Rags are imported into this country from almost every part of the world in which people are sufficiently civilized to wear clothing. I am informed, however, that at the present time the imports of foreign rags are comparatively small, as the low prices which they now fetch will not pay for freight. Those coming into the English market are principally from the Continent of Europe. They are imported in largest quantities at the ports of Goole, Hull, London, and Liverpool. Foreign rags ordinarily are compressed by hydraulic presses into hard and compact bales before shipment. Other rags are collected in this country, along with waste substances of other kinds, by people commonly called "marine store dealers," from whom they pass, through the hands of rag merchants and brokers, into those of the manufacturers. A very dirty class of rags is collected from the dust hills on which the refuse of London and other large towns is tipped. Rags of different primary classes, as cotton and woollen, are collected separately, and those of each class often undergo one or more sortings before they come into the hands of the manufacturers.

Paper mills are to be found in most parts of England, and the consumption of cotton rags is therefore distributed over the country. On the other hand, woollen rags are re-manufactured chiefly in the West Riding of Yorkshire, in the district around Dewsbury, at which town large sales of rags by auction take place twice a week; also in Gloucestershire and adjoining counties in the West of England, and in the neighbourhood of London.

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* Silk rags do not appear to be utilised, except as manure.

Shoddy manufacture.

Woollen rags go to the shoddy manufacturer, by whom they are torn up into an artificial wool, to be used again, with or without the addition of a proportion of new wool, for weaving into cloth, or into fabrics with a cotton warp, called "linseys." The rags are first dusted in a machine. The seams and linings, which contain cotton, are then removed by women who at the same time sort the rags into different qualities. They are then placed in a machine called a "rag-breaker" or "devil," in which they are passed between rollers and presented to a rapidly revolving drum set with numerous sharp iron teeth, by which they are torn up into fibre, a considerable amount of dust being set free at the same time, which is carried off by a fan and collected. The fibre is then "scribbled" in a machine in which it is repeatedly combed out by a series of wire-covered rollers, and is converted into a soft homogeneous wool, fit for the cloth manufacturer's use. Sometimes, but not always, the rags after being torn up are dyed; if not dyed, "pure" wool rags do not undergo any process of which it could be affirmed that it would with certainty destroy infectious matter, though it is probable that any such matter which they might contain, being attached to the surface as dirt, would be removed with the dust, or lose its activity by exposure to the air.

Wool extracting.

Rags of mixed wool and cotton, if containing sufficient wool to make it worth while, are subjected to a process called "carbonizing" for the purpose of extracting the wool. There are two ways of doing this. In the wet way the rags are steeped in sulphuric acid somewhat diluted, at a temperature of 160–190° F., then rinsed in water and dried in a stove. In the dry way the rags, spread out on racks, are heated for some hours in a stove in an atmosphere of hydrochloric acid gas, evolved by pouring sulphuric acid on common salt in an iron retort, or by heating the crude hydrochloric acid obtained as a by-product in alkali works. By one or other of these processes the cotton fibre is destroyed, being converted into a powdery matter, probably glucose, which flies off as dust when the rags are beaten, but the wool, being unaffected by the acid, remains, and undergoes further processes for conversion into shoddy. Either the wet or the dry process of wool-extracting would effectually destroy any infectious matter that might be present.

Manure.

Woollen rags are also used as manure, especially for hops; those rags which are too old, rotten, and dirty for shoddy making being used for this purpose, as is also the dust collected from the rag machines.

Flock making.

Flock making is carried on on the largest scale in the West Riding of Yorkshire, but there are mills also in Surrey, Gloucestershire, Lancashire, and other counties. The rags of which the commoner qualities of flock are made are the refuse of the shoddy trade, viz., what are called "heavy linseys," *i.e.*, materials of mixed wool and cotton not containing enough wool to be worth extracting, such as "shallies" (*i.e.*, old dresses), seams of woollen garments (ripped off by the sorters at the shoddy mills), and other articles of a character so miscellaneous as to defy description. Old carpets, consisting of wool on a backing of hemp or other vegetable fibre, are used for making a better kind of flock. The above materials may come from any part of the world, but principally, I was told, from England and France; but by the time they reach the flock manufacturers' hands they have commonly been so mixed and sorted that it is impossible to trace their origin. The rags from which flocks are made are often far from clean, but their character in this respect will depend upon the quality and price of the flock, which vary greatly. Thus at Mr. Robb's factory at Ossett Spa, a superior kind of flock, made of new wool from the

combings of blankets, curled, was sold at 1*s.* ½*d.* per lb. On the other hand the cheapest kind of flock made by Messrs. Sanderson, of Batley, was sold at 6*s.* 6*d.* per cwt.; this was made of rags of the coarsest and most dirty description.

Process of manufacture.

The process of manufacture is as follows: The rags on being taken out of the bale are carried by hand to the rag-grinding machine and placed on an endless band which carries them into the grip of fluted rollers, and the latter hold them to be torn by the teeth of a rapidly revolving cylinder, similar to that by which rags are torn into shoddy, except that the teeth are shorter and not so sharp,—in fact the cylinders of which the teeth are worn out for shoddy making are used for making flock. This machine is boxed in, and the dust is drawn out by a fan. The flock falls to the bottom, and is gathered in armfuls and packed in bags. Or in some cases the flock is shot through a flue by the current of air produced by the rapid revolution of the cylinder, into another machine, in which it undergoes a process of dusting. The amount of dust in unwashed rags is considerable, from 25 to 50 per cent. of the rags used, according to their quality; dirty rags of course give more dust than clean ones, and wool gives more than cotton. The dust is inflammable, and occasionally fires and explosions have been caused by the heat generated by the friction of the revolving cylinder, especially if rags have been put in hot. To avoid this danger the rags are sometimes damped by sprinkling water over them before tearing up. The dust is conveyed to a dust chamber and is collected from time to time and sent to the hop-growing districts for manure.

The above description applies to the manufacture of rag flock as carried on in Yorkshire. In Gloucestershire a different process is in common use. The rags are first chopped by hand on a block. They are then pulped in a machine similar to that used in paper mills; this consists of an elliptical iron tank containing a revolving drum set with angular iron ribs, which works against a plate similarly armed. The rags, immersed in water, rotate in the tank, and are brought in turn under the drum, by which they are broken up. The process occupies an hour and a half; a stream of water running through the tank all the time. The flock is then dried, first in a centrifugal wringing machine, and then in a stove; and finally is curled in a machine with revolving blades.

Flock is also made in the Gloucestershire mills by the Yorkshire method, but the rags usually undergo a preliminary washing, passing under a paddle-wheel in a tank similar to that above described, and being afterwards dried. At the Wandsworth Flock Mills, Surrey, another washing process is in use, in addition to that last mentioned; the rags are placed under heavy wooden hammers, similar to the "stocks" used for fulling cloth, by which they are beaten for an hour under a stream of tepid water. This process, unlike the tank, does not require the rags to be first cut by hand: it is used for carpets; the tank process for flannel.

Processes of purification.

In Yorkshire the adoption of any process for the cleansing or purification of the rags before they are torn up appears to be exceptional, at any rate as regards the cheaper qualities of flock. The most frequent process appears to be washing, which is done when specially ordered. Messrs. Sanderson, of Batley, stated that washing with the subsequent drying would add 4*s.* per cwt. to the cost of the flock; they said that they had not had occasion to use their washing machine this year, and the appearance of the machine certainly bore out this statement.

Washing.

In the West of England, on the other hand, where water is plentiful, and a better class of flock is made, a large proportion of the flock is washed; at some mills, as those of the several Messrs. Grist, near Stroud, none

but washed flocks are made. Some of the West of England manufacturers, however, have felt themselves, as they say, reluctantly compelled in these days of low prices and keen competition to manufacture unwashed flocks, in order to hold their ground against the Yorkshire makers.

At the factories where the cheapest qualities of flocks are made some of the rags were seen to be very dirty, and all were ground up together. At some factories, however, exceptionally filthy rags are rejected. Rags are sometimes met with which are soiled with blood or excrement, but I did not hear of poultices being observed, or anything which would lead to the inference that the rags had been used by sick persons. Such things would be more likely to be met with among calico than linsey rags. The rags are often infested with fleas and moths, but other vermin are said not to be often met with.

Washed flock is said to be less liable to be damaged by moths than that which contains the dirt.

Chemical solutions.

Two Yorkshire manufacturers, Messrs. Robb, of Ossett, and Illingworth, of Batley, use in the case of inferior flocks a solution of a permanganate for damping the rags before tearing up. This is cheap, and would help to remove any offensive odour that might be present, but is not likely in the quantity used to have much effect in the way of disinfection properly so called.

Illingworth's patent disinfector.

Mr. Illingworth has also patented a machine for the disinfection of rags for flock making by heat and sulphurous acid gas. His machine consists of an iron cylinder with a door at one end, and with double walls forming a steam-jacket. Inside this cylinder is a revolving cylindrical cage with prongs which catch the rags and lifting them turn them over and over. A charge of rags is from 1 to $1\frac{1}{2}$ cwt. At one end of the machine is a small iron furnace with a flue communicating with the interior of the chamber; in this furnace 4 ozs. of sulphur are burnt with each charge of rags. Each charge remains in the machine 35 minutes. The steam in the jacket stands at 70 lbs. pressure: =316° F., but steam does not enter the interior of the chamber.

Experiments therewith.

In order to test the action of the machine a registering thermometer was embedded in a groove in a long wooden bar with perforations opposite the bulb. This arrangement was necessary to prevent the thermometer being broken, or its index displaced, by the motion of the cylinder. A piece of iodide of starch paper was wrapped up in a rag, and both it and the thermometer in the bar were placed in the machine in the middle of a charge of rags and allowed to remain 40 minutes; the cage, turned by an engine, revolving all the time. At the end of the period a thermometer on the bottom in the space between the cage and the steam-jacket registered 273° F., but that in the bar only 169° F. The iodide of starch paper was bleached by the sulphurous acid gas except in the folds, where it retained its colour. In other experiments, after 50 minutes, the thermometer in the bar reached 177° F., and after $1\frac{1}{2}$ hour, 217° F.

In my report on Disinfection by Heat (Annual Report of the Medical Officer of the Local Government Board, 1884), are recorded experiments tending to show that the penetration of heat into textile materials exposed to hot air is greatly aided by moistening the air. At my suggestion, in view of these experiments, Mr. Illingworth had a $\frac{3}{8}$-inch steam pipe connected with his machine so that a jet of steam could be admitted into the interior, at the same time omitting the sulphur vapour. The result was that, although the steam pressure in the steam-jacket fell to 65 lbs.: =312° F., at the end of 35 minutes the thermometer in the bar recorded a temperature of 216° F.; so that when steam was used a temperature which can be considered sufficient for disinfection was

attained in little more than a third of the time necessary with dry heat. The rags, after being removed from the chamber and allowed to cool, were not appreciably damp ; indeed Mr. Illingworth finds that rags lose weight in the chamber even when steam is used.

Mr. Illingworth has invented another machine for disinfecting rags in the bale, but I regret that it was not in use at the time of my visit. It is a steam-jacketed chamber, but the special principle is that he displaces the cold air from the interstices of the bale by exhausting the chamber with an air-pump, and allows its place to be taken by chlorine or sulphurous acid gas let in by opening a valve.

Adulterations of flock.

Cheap as the inferior qualities of flock are, they are yet liable to be adulterated. The fibrous dust shaken out of woollen materials, as stockings, by the shoddy manufacturers is used for this purpose. The residue of the oily waste from the clothweavers, after the oil has been as far as possible recovered by hot pressing, is sometimes used to mix with flock, but this practice is scarcely considered by the trade as legitimate, and one manufacturer, not very particular about cleanliness, told me that he had given it up, as he found that the greasiness and bad smell which it gave to the flock caused much dissatisfaction among his customers. Still this oily waste is not likely to convey infection.

At one factory I saw an iron tank containing liquid with a thick black putrid scum, like that which collects on the surface of a sewage tank, but more fibrous. I was told that the contents of this tank were the refuse and sweepings of the yard and workshops, and that once in six months or so they were washed and dried in a stove, and then were considered to make good flock, being sold at more than twice the price of the lowest quality.

Possibility of transmission of infection.

As regards the possibility of the transmission of infectious diseases by flock made from infected rags, I have made inquiries of a number of medical officers of health in the rag-working district of the West Riding of Yorkshire and elsewhere, and of flock manufacturers, rag merchants, and upholsterers; also, in respect of the dust, of medical officers of health and manure merchants in the hop-growing counties. The result of these inquiries has been to show that while workpeople engaged in the manufacture of flock suffer from certain symptoms produced by the irritation of inhaled dust, instances in which infectious disease had been contracted by them were scarcely to be met with. Indeed, many medical officers and manufacturers of large experience had never known any instance of an outbreak of infectious disease which could be attributed to rag-infection. A few cases were heard of in which persons who had been handling woollen rags for shoddy making had contracted small-pox or other infectious disorder, but the only case at a flock factory was attributed, not to infected rags, but to the re-making of a flock bed on which a small-pox patient had died.

In a report already mentioned, made in 1881, I quoted a number of outbreaks of small-pox among rag-sorters at paper mills ; and since that date a good many others have been reported, some of them being at mills at which previous outbreaks were recorded in my report, some at other mills in different parts of the country. There is a common belief that woollen articles are more apt to retain infection than cotton or linen ones ; but, so far as my inquiries go, workers among woollen or partly-woollen rags are exposed to less danger of infection than workers among calico rags. The explanation I believe to be that the latter consist largely of articles which come into close contact with the body, such as underclothing and sheets, and are therefore more likely to be

infected by a sick person, at any rate by one lying in bed, than woollen articles are. In corroboration of this view it is to be noted that the paper mills at which outbreaks of small-pox have occurred have been with few exceptions mills at which the best class of writing papers, made from white rags, are manufactured; sorters of coloured rags being seldom attacked. Probably also woollen rags undergo less handling than the rags at a paper mill do, as those for the best writing papers are cut up small by hand.*

Experience of flock makers.

The following are the instances of which I have been able to hear, in which infectious disease has been suspected to have been contracted from woollen rags or flock:—

Mr. Thomas Robb, flock manufacturer, Spa Mill, Ossett, Yorkshire, says:—

> "My old workman, who says that it is over 17 years since he left me, says that the following case occurred before he left:—
>
> "A bed was sent to my place to be re-dressed, but he refused to do it, or allow it to be unloaded from the dray at all. He stated then (and repeated last week) that a bed had been sent about a month before to Etchell's flock factory at Horbury to be re-dressed; the man, named Smith, who fed the machine, took small-pox and died. His fellow-workman, who 'shook' it, was also taken ill of the same disease, but recovered. It was afterwards ascertained that the bed sent to Etchell's had been lain on by a person who died of small-pox. He says that the bed, although a flock one, was not a rag-flock bed. I have been 21 years in the trade here, and the above is the only instance I have known, or rather heard of, of a workman having caught an infectious disease from the material he was using.
>
> "Etchell and Co. failed and left Horbury about six or eight years ago.
>
> "I have always refused to re-dress a bed since."

I made further inquiries at Horbury and neighbourhood, but could not learn anything more of this case.

Among other workers in woollen rags.

Mr. Butterfield, then medical officer of health for Bradford, Yorks, in his annual report for 1879, mentions the case of an unvaccinated girl aged 15 who was taken ill with small-pox. There had been no case in the borough for many months, and the patient had not left the neighbourhood of her home. On inquiry, it was found that she had been temporarily employed at a wool-extracting establishment sorting rags, a large proportion of which had come from London, where small-pox had been very prevalent. In a few days another young woman employed on the same work exhibited symptoms of the disease. A few more cases, difficult to trace, but probably springing from the same source, occurred.

Mr. Greenwood, medical officer of health, Ossett, states that in 1880 a young woman working as ragsorter at a rag warehouse in Ossett was taken ill of small-pox. She had been working on "skirtings"—mixed cotton and wool for "extracting." She lodged at a mangle-house, and the case was at first concealed and proved the starting-point of a local epidemic, the district having been previously free.

Mr. Greenwood has met with other cases, produced apparently in a similar manner, but not recently. He also stated that people who work

* The explanation of the fact, if fact it be, that outbreaks of infectious disease are more frequent among workers in cotton and linen than among workers in woollen rags, does not seem to be that there are more rags of the former class in circulation. In the five years 1880–84, the amount of woollen rags imported into the United Kingdom was 180,831 tons; of other rags, 142,391.

among rags are liable to contract itch. (Tardieu, *Dictionnaire d'Hygiène*, Art. *Chiffonniers*, makes a similar statement.)

Mr. Francis Wood, medical officer of health, Wakefield rural district, has met with several cases of small-pox originating among ragsorters, but more at paper mills than among sorters of woollen rags. In a case occurring in June 1881, the patient, who resided in the district of the Sandal Magna Local Board, had been working up to the time of her illness in sorting rags at a shoddy mill in Wakefield.

In April 1885 he reports that a woman living at East Ardsley was attacked with small-pox. She had been working at a rag mill in the neighbourhood; but she had visited at Leeds, in the neighbourhood of which town there had been cases of small-pox. The rags which she had been working at were "shallies," *i.e.*, old dresses (women's) from London; they were for carbonizing to extract the wool, not for flock making.

Dr. Wade, medical officer of health for the borough of Wakefield, also states that all the cases of small-pox which have occurred in that borough during recent years have had their origin among workers in rag factories; but he was unable to give further particulars.

Dr. Goldie, medical officer of health for Leeds, has sent me a report on some cases of small-pox which occurred among ragsorters in that borough in 1878. Of these cases, 1 and 2, girls living in adjoining streets, and working in the same mills, and at the same rags, were taken ill, the one on April 1st, the other about four days later. Case 3, sister of case 1, living and sleeping with her sister, and also working at the same bench with her in the mill, was taken ill on April 11th. (The dates seem to show that it is at least as probable that she took the disease directly from her sister as that she was infected by the rags on which they had both worked.) Two other cases of small-pox subsequently arose through personal communication with the above. There had been no previous cases in that part of the borough. The suspected rags, and all likely to have been in contact with them, were at once disinfected by chemical means and dry heat; their previous history was not ascertained.

Mr. Steele, late medical officer of health, Morley, says in letters:—

> "I only remember one case of infectious fever presumably due to infected rags. This was a lad in the year 1880, who died of typhus fever. He was a ragsorter, and at the same time some cases of typhus had occurred in Leeds which were supposed to have been due to infected rags. No other case occurred either amongst the other men who worked with the deceased or amongst his own family. Typhus fever is practically unknown in this district, and the lad was not at all in destitute circumstances. I do not know where the rags came from; they were woollen rags used in the manufacture of cloth."

Mr. Partridge, medical officer of health for Stroud and adjoining districts, says:—

> "I have not met with any cases of small-pox in the Bisley district, which includes the shoddy mills in Chalford and Brimscombe, since 1875. At that time we had several arising from the effects of opening bales of infected rags, as the women complained of a sickening smell at the time, and were taken ill with a severe form of the disease."

In 1871 an outbreak of small-pox occurred among ragsorters at the Toadmore mills, near Stroud. In that year it will be remembered there was a widespread epidemic of the disease in this and other countries, and infected rags were therefore likely to be in circulation; but it is said that there had been no previous cases in the neighbourhood of Stroud. The particulars, as given me by the mother of one of the patients and

the sister of another—the statements of the two women agreeing together—are as follows: In one room four women were at work sorting rags; they worked at two bags, two women at each bag. Of the four, three were taken with small-pox, C. (æt. 15), and D. (æt. 16), who worked at one bag, on the same day; B., a young married woman, who worked next them at the other bag, a day or two later. The other woman escaped, as did also the sorters in another room. The rags on which those who took small-pox were working were "shallies," *i.e.*, old dresses, of mixed wool and cotton, for carbonizing; but it was not known whence they came. C. and D. died, and a baby five weeks old, in C.'s family, was taken with small-pox a fortnight after her, and died. Mrs. B. recovered, but her husband took the disease and died.

The "woolsorters' disease" which occurs in Bradford and neighbourhood among men engaged in handling the fleeces of animals which have died of anthrax has been described by Mr. Spear in the Annual Report of the Medical Officer of the Local Government Board for 1880.

Of upholsterers.

I have not been able to hear of any cases of infectious disease among upholsterers, or the public their customers, traceable to the use of infected rag flock. Doubtless the risk of infection to which these classes are exposed is much less even than that of the flock manufacturers, both because any infectious matter which the rags may have contained has in large part been got rid of in the form of dust, and also because any that may remain will be older and thus likely to have had its activity diminished or lost. Cases, however, of infectious disease among the general public from the use of infected flock, if such occurred, would probably be very difficult to trace and are not likely to be recorded.

I learn that large upholsterers and firms of repute use, as a rule, wool or flock made of new or washed material, and that the coarser qualities are chiefly used by small and obscure tradesmen, among whom also the still more objectionable practice is sometimes adopted of using the flock out of old beds and furniture for the stuffing of new. The cheapest sort of flock is said to be used for stuffing mattresses for emigrant ships, being thrown overboard at the end of the voyage.

The greater part of the materials used by upholsterers of repute for stuffing beds and furniture are not likely to be infected. Feathers are purified by steam heat. Horsehair, being purified by washing, is curled at a very high temperature, about 300° F. "Millpuff" is the woolly waste beaten out in the process of fulling which cloth undergoes in the course of manufacture.* Cotton flock, a cheap material largely used, is the refuse of raw cotton. Other materials of a vegetable nature are straw, chaff, cocoa-nut fibre, a kind of coarse wiry grass resembling the mat-grass of our sandy coasts, and a kind of seaweed (apparently a Zostera), said to be imported from Russia, and called in the trade "ulva." Such materials, unless taken out of old furniture, have not previously been used. The better classes of flocks are made of new or comparatively clean material, so that it is only the inferior classes which are at all likely to be infected.

The dust which flock retains as received from the manufacturers is further removed by a process of beating and carding at the hands of the upholsterer before the flock is used for stuffing.

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* The short flock used by paper-stainers in the manufacture of flock wall-papers consists of the superfluous "nap" from the surface of cloth, sheared off in the process of manufacture.

Of users of rag waste as manure.

The following instances are all those which I have been able to hear of in which disease has been attributed to the handling of infected waste used for manure :—

Dr. Robinson, medical officer of health for East Kent, writes :—

"I have a record made on April 29, 1877, of four cases of blood-poisoning derived apparently from infected wool waste (I believe shoddy). They occurred at separate cottages some distance from each other, but the sufferers had all been at work engaged in carrying wool waste. One man whom I saw had erysipelatous inflammation on the hands and at the back of one ear, and was much prostrated. He informed me that on account of the land being heavy it was difficult to distribute the manure by cart and shovel, and in consequence the manure was carried in a basket and cast on the land by hand in the same way as wheat is hand sown. Further, he told me that he had a habit of scratching the back of the ear, the spot which had evidently been inoculated.

"The other three men suffered from sickness, diarrhœa, and febrile disturbance. The symptoms were obscure, but more like septic poisoning than anthrax. No fatal case occurred, but one of the latter three men was very ill, viz., the one who carted the wool waste from the station.

" I do not remember any cases of small-pox arising from infected wool waste. In some other instances of illness occurring among persons who attributed their attacks to poisonous wool waste the evidence on the subject was not very clear."

Dr. E. F. Fussell, medical officer of health for East Sussex, mentions a case in which a lad who had for a week or more been employed in spreading with his hands "fur waste" manure over a field, was taken ill of scarlet fever which was attributed to infection in the manure, as there had been no previous cases in the neighbourhood, and the lad had been nowhere away from home except to his work. The "fur waste" is described as the refuse of fur and felt manufactories; it would not appear *a priori* to be a material very likely to be infected, and it hardly comes within the scope of this report.

Noxious effects of inhaling dust.

Workers in flock factories, on commencing to work among the dust, suffer from a malady known among them as "flock fever." Mr. Illingworth, a large manufacturer, says that he has never known anyone escape it. The symptoms are described as those of a severe catarrh of the bronchial passages, viz., shivering, difficulty of breathing, cough, soreness of the chest, and expectoration of mucus charged with dust. In about a week's time, if the man continues at work, a tolerance of dust is established, the symptoms subside, and do not recur so long as he keeps at the same work: but on leaving it off the tolerance for dust is soon lost, and on returning, after a week or two's absence, a man suffers again as at first. I am even told that the men will not empty the dust-chamber on a Monday, as they would suffer more from the dust then than if they had been at work the day before.

Men who can eat well are said to be comparatively little affected by the dust, but those whose appetite fails are apt to break down. Heavy drinkers, on the other hand, cannot stand the dust well, and men are said to cough much at their work if they have been drunk the night before. A "cold," with catarrh of the air-passages, also causes the irritative effects of the dust to be felt.

When men have got used to the dust the work is not considered unhealthy. Among some 25 men constantly employed by him about the rag machines, Mr. Illingworth says that only one has died in the

past 12 years; he was a man who drank heavily, and the dust used to punish him much. He had a bad cough and died of inflammation of the lungs.

This so-called "flock fever" does not appear to come under medical observation, but is treated by domestic remedies, as for a common cold. In fact the only way is to continue at work, for if the sufferer gives up he has to go through it all again. The condition of the workshops has been much improved of late years through the operation of the Factory Acts by boxing in the rag machines and drawing off the dust by fans; and the men are said to suffer much less from dust than they formerly did. If the rags have been washed before tearing up, much less dust is evolved, and what there is is less irritating than that from dirty rags.*

Upholsterers' men, when working among flock, are said also to suffer in some degree from the effects of inhaling a dusty atmosphere.

Suggested precautions.

As regards the precautionary measures which may be taken against the spread of infectious diseases by rag flock, I find that three classes of measures may be recommended; the first two being specially for the protection of the work-people; the third for that also of the public at large:—

Vaccination.

A. *Vaccination.*—Against small-pox, which is the disease most likely to be propagated by infection contained in rags, vaccination, with re-vaccination on arriving at adult age, is, when properly performed, a very efficient, if it be not an absolutely certain, prophylactic; and rag merchants and manufacturers should make it a condition of their service that every rag worker should have been efficiently vaccinated and re-vaccinated.

Avoidance of dust.

B. *Avoidance of Dust.*—Much has been done in this direction, and it would seem with beneficial results as regards the general health of the workpeople. Any further steps in the same direction that may be practicable should be taken. The general cleanliness and ventilation of the premises should be looked after, and facilities afforded for habits of personal cleanliness on the part of the workpeople.

C. *Cleansing and Disinfecting of Rags.*

Cleansing

(*a.*) Washing of the rags, thoroughly performed, as by one of the processes already described, would in all probability remove any infectious matter adhering to the rags. It is not, however, any protection to the work-people. On the contrary, the additional handling required in the early stages would tend in the opposite direction. The principal danger appears to be in the first opening of the bales, and therefore any measures of disinfection, to be effective, must be applied to the rags while still in the bales.

and disinfection of rags.

(*b.*) Chemical disinfectants, as permanganate of potash, sulphurous acid, or chlorine gas, may be of use as deodorants and for destroying vermin with which the rags may be infested, but the result of recent experiments has been to show that the efficacy of such agents for the destruction of morbid poisons has been greatly overrated, and that they cannot be depended upon for that purpose unless they are in a comparatively high degree of concentration, and allowed to act for a considerable period, in which case they may injure the fabrics to be disinfected. Their disinfecting power is, however, increased at high temperatures.

(*c.*) On the other hand it has been shown that heat, especially moist heat, readily destroys the activity of morbid poisons. In my report on

* This advantage, it may be remarked, is gained at the cost of a certain amount of river pollution; the streams carrying off the organic matter, which would otherwise find its way to the land as manure.

Disinfection by Heat, before quoted, it is shown that the spores of the bacillus anthracis (the minute parasitic organism which produces wool-sorter's disease), the most refractory of known infective materials, were destroyed by an exposure of five minutes to 212° F. in steam or boiling water; and by one of four hours to 220° F., or of one hour to 245° F. in hot air, dry or moist, while infective organisms devoid of spores were destroyed by one hour's exposure to 220° F., in air. Steam was found to penetrate into badly-conducting materials, such as bales of rags, much more rapidly than hot air; in the case of hot air the penetration of heat was found to be aided by moistening it. Moist heat is the best agent for disinfecting rags, since it will penetrate them in the bale and thus avoid the necessity for unpacking and the consequent handling of the undisinfected rags, and the most effectual way of applying heat with moisture is in the form of what is called "dry" or superheated steam. In Lyons's patent steam disinfector a temperature of 206° F. was attained in the centre of a press-packed bale of rags weighing 5 cwt. in three hours, and one of 252° F. in four hours. In the latter experiment the increase of weight of the bale due to moisture condensed from the steam was only four per cent. It is stated that in an American apparatus in which superheated steam is injected into the centre of the bale through hollow screws, effective disinfection can be carried out in considerably shorter time even than that mentioned above.* Of Mr. Illingworth's machines for disinfecting rags I have spoken in an earlier part of this report, and I have no doubt that loose rags can be effectually disinfected in the one that I saw in action. Whether a press-packed bale could be heated through in a reasonable time I do not know.

Ought disinfection of rags for flock making to be compulsory?

In my report on rag infection in the paper trade it was shown that, desirable as it might be for the safety of the workpeople, that all rags should be disinfected before being sorted, it was difficult to recommend that such disinfection should be made compulsory, for the following reasons:—

The law already forbids under penalty the selling, transmission, or exposure of infected articles, so that if infected rags pass into the market, it is through a breach of the law on the part of the original vendor, and it would hardly be just to require manufacturers to guard against such a possible breach on the part of other persons by disinfecting all rags which passed through their hands; while in the absence of any character by which infected rags could be recognised—and there is no such character,—it would be impossible to discriminate between the few cases in which disinfection was required and the many in which it might safely be omitted.

These considerations apply also to the case of rags used for flock making, but there are some differences in the two cases.

(*a.*) In the case of paper making, the question is only that of danger to those who sort the rags, and not to the public who buy and use the paper, for the rags after sorting undergo processes by which any contagium which they may contain is certain to be destroyed. Flock, on the other hand, does not necessarily undergo any process of purification beyond the removal of the dust before coming into the hands of the public.

* I am informed by Messrs. Cohen & Co., rag merchants, of Great Dover Street, London, who send many rags to the United States of America, in which country the importation of undisinfected rags is prohibited, that they prefer to expose the rags, hung on racks, to the fumes of burning sulphur before shipment, rather than allow them to be subjected by the American authorities to the steam process above mentioned, which is considered by manufacturers to injure the rags. This injury, if real, is likely to be the result of the very high temperature (330° F.) of the steam employed; a temperature quite unnecessary, judging by the results of the experiments to which I have referred above.

(*b.*) In the case of paper-making, any preliminary disinfection of the rags would not improve the quality of the finished paper; it is even feared by paper-makers that the paper would be injured thereby. In the case of flock, a disinfected article would presumably be worth more, certainly it would not be worth less, than a crude one. Disinfection would at all events destroy any insects, such as moths.

(*c.*) On the other hand, there appears to be more danger of infection connected with the rags used in paper-making than with those from which flock is made. Possibly, however, the result of attention being called to the subject may be to show that instances of infection being conveyed by woollen rags are not so rare as at present appears.

Thus, in the case of flock making, the manufacturer does not obtain the same degree of security against the operation of infection contained in the original rags as is obtained by the paper maker; and though it may not be practicable to enforce upon the flock maker a general disinfection of all rags used in his business, yet there must be a variety of means by which he can reduce the danger of infection being conveyed with his rags. To that end, it is to be desired that the attention of manufacturers, upholsterers, and the public should be drawn to the risk of such infection, and to the advantage of a preliminary disinfection of materials.

The advantage of a washed flock over one "in the dirt," as it is called, is already recognised in the trade; only, it is alleged, many of the public will not pay the necessary price for the better and safer article.

Recapitulation.

Recapitulation.

1. Rag flock is a material used for stuffiing articles of bedding and furniture.

It is made by tearing up rags, usually of mixed cotton and woollen nature.

The rags from which the inferior qualities of flock are made are commonly very dirty, and do not, as a rule, undergo any process of purification beyond the removal of the dust.

2. Flock makers and others exposed to rag dust suffer, especially at first, from symptoms produced by the inhalation of dust. They do not, however, appear often to contract infectious disease.

A few cases were heard of in which persons working among woollen rags, or handling rag dust used as manure, had contracted small-pox or other infectious disease, possibly from infectious matter contained therein.

No cases of infectious disease, attributed to the use of infected rag flock, were heard of among upholsterers or the general public.

Workers among woollen rags appear to incur less danger than cutters of cotton and linen rags at paper mills, probably owing to the fact that woollen rags consist mainly of articles which do not come into close contact with the body.

3. The following precautionary measures are available:—

A. Vaccination and re-vaccination of rag workers.

B. Ventilation, cleanliness, and avoidance of dust in rag factories.

C. Disinfection or purification of rags; preferably in the bale. The best disinfectant for the purpose is heat in the form of superheated steam, or hot moist air.

In conclusion, I have to express my obligations to the various medical officers of health, manufacturers, and others who have kindly furnished me with information for the purpose of this report.

No. 8 (*a*).

MILK-SCARLATINA in LONDON in 1885: being a REPORT by Mr. W. H. POWER on certain observed relations between SCARLATINA in various DISTRICTS of LONDON and MILK supplied from a DAIRY FARM at HENDON.

Statement to Board.

ON December 18th, 1885, Mr. A. Wynter Blyth, Medical Officer of Health of St. Marylebone, personally reported to the Board a sudden and extensive outbreak of scarlatina* that appeared to be associated with the distribution of milk from a particular retailer in South Marylebone. He described this retailer as obtaining his supplies from two farms, and the coincidence of the retail milk distribution with Marylebone scarlatina as being limited to that one portion of the milk supplies derived from a certain dairy farm at Hendon. Mr. Blyth further stated that he had visited this farm and had conferred with Dr. Cameron, the Hendon Medical Officer of Health, but that neither he nor Dr. Cameron had been able to discover, in the sanitary circumstances of the farm or in the health of those employed about the farm, any sort of clue to the means by which the milk had become infective. He had not heard of any veterinary examination of the cows.

Hereupon I received the Board's instructions to make inquiry into the whole case, and if occasion should arise, to investigate the conditions at the Hendon farm that might have a bearing on the question of production or dissemination of scarlatina by milk; and further, if any sort of malady among the cows should appear to require investigation, I was to obtain the co-operation of Dr. Klein in such pathological study as was needful.

Personal inquiry.

Inquiry was commenced simultaneously in London districts and at Hendon. The experience of South Marylebone, as observed by Mr. Blyth, was compared with the corresponding facts for other London districts receiving supplies of milk from this Hendon farm. At the same time at Hendon search was made for cases of disease, not only of scarlatina, but of any disease resembling scarlatina; and not only among the families of those employed about the farm, but among their neighbours and in the district generally. The Hendon farmer was made acquainted with the general nature of the inquiry that was going on, and his help was invited in any investigation of his farm and his business that might afterwards become requisite.

Scarlatina found in certain milk businesses;

In the course of a few days, by December 23rd, inquiries in the foregoing sense had been made. It had been learned that milk from this Hendon farm had been distributed by retail in St. John's Wood, in St. Pancras, in Hampstead, and at Hendon, as well as in South Marylebone; it had been distributed in these districts only; and from every one of these several districts—except from St. John's Wood—the same general story was forthcoming. Until the end of November or beginning of December 1885, the district had been for some months exceptionally free from scarlatina; about this date scarlatina had undergone sudden and notable increase in the district; and then and thenceforward

* The diagnosis of "scarlatina," in the cases with which this Report will be concerned, was made without hesitation by every practitioner who had charge of the cases, alike in the metropolis and at Hendon.

a strikingly large proportion of the recorded cases had occurred among persons who proved, upon inquiry, to be customers of a milk retailer dealing in the particular Hendon milk.

At this early time of the inquiry, no special importance could be attached to the circumstance of scarlatina not having been noticed among the customers of the St. John's Wood business.

probably in consumers of Hendon milk

In each of the milk-districts (as I may call them) of South Marylebone, St. Pancras, and Hampstead, other milk besides milk from Hendon had been distributed by the retail dealer vending the particular Hendon milk; and as soon as special prevalence of scarlatina in those several milk-districts became apparent, it was of course seen that, instead of the Hendon milk, these other milks might be in question. This was possible though not probable. For these other milks had come from two different farms (from one to South Marylebone, from the other to Hampstead and St. Pancras), situated in widely separate counties, and distribution of scarlatina with milk not being an every-day occurrence, it was much less likely that absolutely distinct farms thus widely separated had at one and the same time been supplying to neighbouring districts in London milk having the same special concern with disease. It was much more likely, therefore, that the Hendon share of the milk, being common to the three businesses, had been the responsible agency.* And further, Mr. Blyth had ascertained in regard of the South Marylebone milk business that certain customers supplied with Hendon milk, *and Hendon milk alone*, had suffered scarlatina.

from a particular farm.

Then, as for antecedent disease among the Hendon population, of a nature to have had concern in the distribution of scarlatina with the Hendon farmer's milk it had, by December 23rd (thanks to Dr. Cameron's thorough knowledge of his district), come to be regarded as out of the question that any infection of the milk by such disease outside the farm could have taken place. It could be said that no scarlatina, nor any illness at all like scarlatina, had affected any of the persons employed about the farm, their families or neighbours, at any such time or in any such way as to influence the farm or its produce. Such few cases of scarlatina as could be heard of at Hendon during 1885 had occurred at a distance from the farm and in families that had nothing whatever to do with the farm.

The foregoing experiences of different districts, and the considerations here presented as arising out of them, were held to constitute a notable presumption that the Hendon farm had been concerned with the scarlatina prevalences. It was a presumption that nowise amounted to proof, especially when it was seen to be an essential element of the problem that outside human agencies had to be set aside as not having been operative. Yet it was enough to give precedence to the Hendon farm as the place where search after conditions of milk infection might most profitably be made; and investigation of the circumstances of the Hendon farm was accordingly commenced without loss of time.†

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* As the inquiry advanced, and the exemption of the St. John's Wood consumers of Hendon milk was seen to be definite and beyond question, the fact appeared for the moment greatly to change the above probability. But on the other side there was the circumstance of a peculiarly intense incidence of scarlatina at Hendon among people who got no milk except from the Hendon farm. More about these occurrences will appear in the sequel.

† Though precedence was given to this investigation, it was not without much hesitation that the inspection of the dairy farm was begun. For ere now it has happened that official visits for purposes of knowledge have been confounded by the public with condemnation of the common sanitary doings of the farmer, with the result of unwarranted disaster to his business interests; and I had Dr. Cameron's assurance that in this case any such condemnation was very far from being deserved.

On Milk-Scarlatina in London; by Mr. W. H. Power.

In passing to consider the possible relations between this farm and the outbreaks of scarlatina which had occurred in the milk districts of various retailers deriving parts of their supplies from the farm, I had the advantage of Dr. Cameron's assistance. This officer had had previous experience of disease associated with the consumption of a particular milk, and as my inquiry at Hendon proceeded he proved himself a very able coadjutor. In what follows respecting the Hendon dairy farm I may claim that my methods and conclusions had throughout his consent and confirmation.

Conditions observed at Hendon.

Sanitary state of farm.

The dairy farmer, though willing to afford and though indeed desirous of affording us every assistance, was utterly incredulous of the presumptive evidence tending to connect disease with the milk supplied from his farm, and till a late period of the inquiry he remained so. His cowmen were perfectly incredulous also. And truly, having regard to the facts that we first elicited, as to freedom from illness of those at the farm and as to the peculiar care given to the sanitary affairs of the farm and its dairy, the farmer's incredulity could not but be regarded as justifiable. He had certainly done his best to avoid known conditions of danger, and had not suspected that any such condition, known or unknown, had been present on his farm. The farm was found to have had especial pains taken to render it, as the phrase is, sanitarily perfect. At the instance of one of the London retailers with whom the farmer had dealings,* the place had for several years been the subject of special supervision by the medical officer of health of the district, my coadjutor in this inquiry, Dr. Cameron. He had seen that the West Middlesex Company's water was laid on to the farmhouse, to the dairy, and each of the several cowsheds; he had seen specially to the wholesomeness, as regards drainage, cleanliness, ventilation, and the like, of the house, the farmyard, the cowsheds, and the dairy; securing for the last all needful appliances for effectual cleansing of dairy utensils by hot water or steam; and, month by month, he had inspected the farm premises with reference to these and similar details, for the express purpose of safeguarding the milk against contamination of any detectable kind. Further, under the same arrangement, Dr. Cameron had specially attended to the health conditions of those employed about the farm and their children, with a view to early detection of any malady among them that might by chance injuriously affect the milk with which they had to do. He had even undertaken to observe and to report to the London retailer, by whom his services were retained, on any occurrences of infectious illness in the neighbourhood of the farm, even though it did not directly affect the families of people employed there. The farmer too who had consented to the exercise of this supervision over his doings, had attended to every suggestion made to him, and had taken every precaution to secure his farm and his milk against any known sanitary fault or misadventure. He had a separate shed for any sick animal, and a separate shed for the observation of newly arrived animals.

Provisional hypothesis of cow disease.

Thus, with Dr. Cameron's aid, the point was speedily reached at which it could provisionally be affirmed of the Hendon farm milk that, if indeed it had caused scarlatina among its consumers, it had not acquired the ability to do so in any commonly accepted way, such as

* This retailer owned the St. Pancras and Hampstead businesses, and will be mentioned in this Report as Mr. Y. He has for some years shown the same solicitude in respect of the other farms from which his milk is brought to London. In other ways, too, he has habitually been on the alert to secure his customers from any risk of milk-infection, and to place his business above suspicion. His attitude towards sanitary matters in their wider aspect has been much in advance of his fellows; and thus the abundant aid he has furnished to the present inquiry has been correspondingly of the greatest value.

through unwholesome conditions of water or drainage, or through careless handling of milk or milk utensils by persons carrying scarlatina infection. Nor, during the long subsequent acquaintance with the farm gained in the course of this inquiry, did any reason appear for modifying this conclusion.

It was not long, therefore, before we found ourselves confronted with the alternative, which thenceforth constituted itself into the hypothesis which we had to examine, that the cows themselves must have had something or other to do with any scarlatina which had been distributed along with their milk.

Our reliance for the discovery of such a something, and for an understanding of its nature, lay in ascertaining in detail every parallel between the doings at the dairy farm and the observed scarlatina.

Relations of Scarlatina cases to farm operations.

From the point of view now reached, every peculiarity of scarlatina incidence on the various districts supplied with milk from the Hendon farm acquired a new importance. Exemptions, specialities in point of time, and of extent of prevalence, now claimed to be considered under the aspect of possible relation with the operations of the farm. The history of the observed scarlatina, thus investigated with all attainable exactness, is given in summary in the table subjoined. Leaving to the health officers of the several districts to narrate, in the health interests of their districts, the local characters of the outbreaks, I here show for each retailer of the Hendon milk the locality of his operations, the amount of this and of other milk distributed by him, and the dates of notable incidence of scarlatina on the consumers of milk delivered from his shop, together with such facts as are to be had about the relative amounts of scarlatina in the customers of the several businesses. I designate the retailers by letters rather than by their names.

Retailers of Hendon Milk.	Milk-District situated at	Total Amount, in Barn Gallons, of Milk distributed Daily.		Date of Notable Incidence of Scarlatina on Customers of Retail Business.	Degree of Incidence at one and another Period.
		Hendon Milk.	Other Milk.		
Mr. X -	South Marylebone.	63	10	End of November and early December to date of inquiry.	Customers suffered heavily and in increasing numbers up to date of inquiry.
Mr. Y (1*)	Hampstead -	18	25	End of November or early December, and Mid-December.	Customers did not suffer nearly so heavily as Mr. X's customers. They were attacked in two groups, one a small group, limited in time at the beginning, the other a large group, from the middle of December to the date of inquiry.
Mr. Y (2*)	St. Pancras -	6 or 7	45	Early December and Mid-December.	Comparatively few customers suffered. Attacks, however, grouped in time much as in Y (1) business.
Mr. Z -	St. John's Wood.	20	4	—	No scarlatina among customers up to date of inquiry.†
Mr. P -	Hendon -	1 or 2	—	Early December -	Number of families consuming the milk day by day not a dozen. Two of them suffered; the earliest invaded being attacked near end of first week of December.

* Mr. Y. had two retail milk establishments, Y (1) in Hampstead, and Y (2) in St. Pancras. Hendon milk was delivered to him at his Hampstead place of business, and there only; from hence some of it was transferred by his own men to his St. Pancras establishment.

† But see page 84, para. (*c*.)

Of the special phenomena that were learned about the scarlatina outbreaks, and that are shown in summary on this table, those which established the most important claim to recognition by the inquirer into the farm operations, were seen to be as follow :—

Specialities of London scarlatina.

(*a.*) In those four districts (the milk districts of a former paragraph) wherein scarlatina had shown an extravagant incidence upon the milkman's customers (probably, as we have seen, upon the consumers of the Hendon milk), the disease had begun its peculiar incidence *at one and the same time*, namely, *about the end of November or beginning of December.*

(*b.*) In one of those districts (that of Mr. X) scarlatina continued *day by day, and with increasing force up to the date of the inquiry*, to attack the customers of the retail business.

(*c.*) In two other of those districts (those of Mr. Y's two businesses) scarlatina behaved in a different fashion. In each district, after attacking in some number *for a few days at the end of November and beginning of December* the customers of the business, the disease showed *no fresh attacks for about ten days* (the period of intermission was short, but was quite clearly and sharply defined), and then *about the middle of December attacked them again in larger number, and continued to do so up to the date of inquiry.*

(*d.*) In the fifth district (that of Mr. Z's business) *no scarlatina whatever*, either at the end of November or subsequently, *down to the time that the investigation was proceeding*, had been learned of by the best inquiry that could be made in the parish.

In the study of the farm operations, which was now set on foot for the detection of conditions parallel to these special phenomena, the most striking phenomenon—one which, indeed, demanded explanation if any relation of the Hendon milk to the disease were to be upheld—was this definite exemption of the St. John's Wood people who had dealings with Mr. Z. It was, indeed, a remarkable fact. Mr. Z got five-sixths of his milk from the Hendon farm, and distributed an ample quantity of it among numerous customers. Yet there was a total absence of scarlatina from among these customers.

Their connexion with new conditions at farm:

Examination of the circumstances of the cows at the Hendon farm was now directed to ascertain whether *any new condition pertaining to the cows* had arisen in the farm or had been contributed to the farm business at such time and in such way as to be coincident with the ability of the milk to produce scarlatina in its consumers, first, at the end of November in four milk districts, afterwards, throughout December, in Mr. X's milk district, and after an intermission in December, in Mr. Y's two milk districts; while the condition in question was absent from the cows that furnished milk for Mr. Z's business.

The process of inquiry was tedious, involving investigation of a variety of circumstances, such as food of cows, calving of cows, health of cows, arrival and departure of cows, and so forth; and, up to a certain point, it proved barren of result. For a long time nothing could be heard of that was new or changed. During many weeks, or even months, before the scarlatina outbreaks among milk consumers, no change had been made in the food of the Hendon cows; much of this food had been the produce of the farm; the source of other kinds of food had remained unaltered, the quality of the food had not (the farmer averred) changed or deteriorated. So too, as regarded calving of cows, and health of cows. The business did not include the rearing of calves; it was a milk business, pure and simple, the cows being "stall-fed" all the year

round, and, as matter of fact, no cow had calved at the farm since September. As to health of cows, it was confidently affirmed that, for months past, not one of them had suffered any illness; indeed, with the exception of everyday trivial ailments, the cows had been, it was stated, particularly free from all maladies to which stall-fed cows are admittedly more liable than other cows.

among newly arrived cows.

But upon passing to consider in detail the comings and goings of cows to and from the farm, some important information was forthcoming, and the inquiry began to assume a more hopeful aspect. The business of the farm being an affair of milk production only, had required a high average yield from the cows kept there; so that cows, as they "dried off," had been in practice replaced by fresh and "newly-calved" cows purchased as occasion required from the country. And it turned out that on the 15th November, three newly-calved cows, purchased from Derbyshire, had been received into the business.* Before November 15th, no new cows had been received since the middle of October; and after November 15th, none had been received until December 4th, when four additional cows had been purchased from Oxfordshire.

In the addition to the dairy farm on November 15th of three newly-calved cows, there appeared a circumstance eminently worth further exploration. For (*a*), it was seen that the arrival from Derbyshire of those newly-calved cows (November 15th) did in fact shortly precede the first occurrences of scarlatina in the four milk districts, namely, at the end of November or beginning of December; so that the cause of scarlatina (whatever it was) was actually manifested in these four districts just after† the time when the milk of those cows came to be included in the produce of the farm. Accordingly, the next questions that arose were, had there been anything (*b*) in the distribution of the milk of those particular cows, or (*c*), in the subsequent relation of those cows with the new-comers of December 4th, or of either set with other cows in the herd, parallel to the observed specialities of scarlatina incidence upon the four infected milk districts? Going on to seek answer to these questions in the facts of the dairy farmer's procedures, some further very interesting and suggestive correspondences were presently obtained.

As regards the concern which the several retail milk businesses had with the milk of newly-imported cows, it has to be premised that such cows were not at once added to the stock in the general cowsheds of the farm. In accordance with a custom instituted for the purpose of guarding against the introduction of foot-and-mouth disease, the new-comers were at first placed in what is known as "the quarantine shed," a little removed from the farmyard. New cows are here kept until their freedom from that disease is regarded as assured, usually for a week or ten days. As matter of custom, their milk is not used in the business immediately after calving, but after a while and before the cow is removed from the quarantine shed, it is judged permissible to use the "quarantine milk." At the expiration of this quarantine period newly imported cows are taken from their special shed and distributed according to the requirements of the general business in the three several sheds of the farm along with the other cows already there.

The particular batches of animals received on November 15th and December 4th were dealt with on this plan. The precise period of

* The dealer who was believed to have purchased these cows in Derby market, and who sold them to the Hendon farmer, resolutely refused all information whatever.

† It was necessarily "after"; for with scarlatina as with other infectious diseases, there is an interval between the date of reception of the infection and the first manifestation of the disease. In scarlatina this interval is known to be less than a week.

quarantine in the case of each batch had not been recorded, but it was believed by those about the farm that the 15th November cows had stayed in the quarantine shed longer than usual; the 4th December cows for not more than a week.

Specialities of distribution of their milk

At the date—the third or fourth week of November—at which the milk of the farm, if it had any infective ability, must have acquired that ability, the cows at the farm numbered 90 or 100, distributed in the several cowsheds as follows:—in the "large shed," 40 or 50; in the "middle shed," 30; in the "small shed," 20. At this date, the 15th November cows were still in the quarantine shed. A few days later, somewhere about the end of the month, the 15th November cows were transferred into the general cowsheds, and very shortly afterwards their places in the quarantine shed were taken by the cows received from Oxfordshire on December 4th. These in turn were transferred to the general cowsheds about December 11th.

At the date in question, the distribution among the London retail dealers (I defer for a time further mention of Hendon consumers) of the milk of the cows in the several sheds was effected with much uniformity, each morning and evening, as follows:—

From the "large shed," Mr. X and Mr. X only, was supplied. The milk of the shed did not indeed suffice for his whole requirements, and the balance was made up by a varying quantity of milk from the "middle shed."

From the "middle shed," Mr. X and Mr. Y received their supplies, and not any other dealer. Mr. Y received all the milk from this shed, except what was required for Mr. X, and in so far as this quantity was insufficient for Mr. Y's requirements, the supply to him was made up from the "small shed." As before said, all milk of the farm received by Mr. Y for his two businesses was delivered to him at one place, namely, at Hampstead.

From the "small shed," Mr. Y and Mr. Z received their supplies, and not any other dealer. Mr. Z received all the milk from this shed, except what was required for Mr. Y, and Mr. Z received milk from no other shed.

From the "quarantine shed," milk was being distributed at the date in question: on some days it went to make up Mr. X's supply, on other days to make up that of Mr. Y, frequently perhaps to both of them on the same day. But rarely, if ever, had it been added to churns destined for Mr. Z, for in the routine of the farm his churns were seldom brought out of the small shed before the quarantine milk had been disposed of.

parallel to distribution of scarlatina.

Now as we have seen, the chief facts as to time-incidence of scarlatina on the four milk-districts of South Marylebone (X), Hampstead and St. Pancras (Y (1) and Y (2)), and St. John's Wood (Z), were as follow:—

Mr. X's customers began to suffer at the end of November and continued to suffer in increasing number up to the date of inquiry.

Mr. Y's customers, in the districts of both his businesses, suffered slightly at the end of November and beginning of December. Then for a while they ceased to be attacked; but about the middle of December they were again attacked in greater numbers and more persistently than before.

Mr. Z's customers had not suffered at all, so far as could be heard of, up to the period that the inquiry had reached.

It will be evident to the reader that, in our search for new conditions within the farm corresponding to the appearance of the milk outbreaks in London, we had now succeeded in finding one such condition, namely, the distribution of the particular milk furnished by the newcoming 15th

November cows. Scarlatina among Mr. X's customers appears soon after the milk of the 15th November cows in the quarantine shed comes to be added to the milk delivered to Mr. X. Scarlatina among Mr. Y's customers appears in Y's two milk districts soon after the milk of these same cows comes to be added to the milk delivered to Mr. Y. Scarlatina among Mr. Z's customers is absent; no milk from these cows is added to the milk delivered to Mr. Z. But this was not all.

Peculiarities of time-distribution of scarlatina

Having in view the other specialities observed in the local behaviour of scarlatina in the several milk districts, it came to be seen at this stage that if the above concurrence was in truth indicative of cause and effect, we must be able to set down *a priori* certain other parallel events which, if they had occurred, would greatly strengthen the inference. This was accordingly done, and when certain probable events had been formulated, inquiry was made as to their actual occurrence.

Taking as a postulate that the likeliest method by which a result producible by the milk of particular cows would become varied or modified, was by variation or modification of the relations of the cows themselves within the business of the farm, the following three propositions were set out as matters of probability:—

(*a*.) In the last days of November or the earliest days of December, a change had probably been made in the manner of distributing the milk produced by the 15th November cows, and most likely this change had consisted in the transference of those cows themselves, or some of them, into the "large shed" and delivery of their milk thenceforward along with the milk of the other cows in that shed.

(*b*.) About the second week of December, some of the 15th November cows, or some of the 4th December cows (which up to December 11th had occupied the quarantine shed), or some other cows that had been during early December in close relation with the 15th November cows, were probably transferred to the "middle shed," and their milk delivered from thence.

(*c*.) It was not probable that at any time up to the end of the second week in December, any of the 15th November cows, nor any of the 4th December cows, nor any cow that had been in close relation with such cows, had been transferred to the "small shed."

parallel to peculiarities of time-distribution of milk.

These probabilities were formulated in view of the special time-distribution of scarlatina in Mr. X's district, and in Mr. Y's two districts, and in view of the continuous exemption of Mr. Z's district. They were not announced in any way to the farmer or his men; and in the search after facts, care was taken to avoid putting leading questions to the people who had been engaged about the cows. Once or twice indeed a statement was made by way of interrogation—to receive the assent of a cowman, who could not divine whence our information had come. In the outcome, it was found that, as matter of fact:—

(*a*.) The three 15th November cows had been, towards the end of November, transferred to the "large shed." Here they all still remained at the date of inquiry, and their milk had been delivered from hence.

(*b*.) The four 4th December cows had been transferred about 11th of December, two of them into the "large shed," the other two of them into the "middle shed"; and in these sheds they were found at the date of inquiry, their milk going into the general supply of the respective sheds.

(*c*.) At no time up to the date of inquiry had any of the 15th November cows nor any of the 4th December cows, nor any other cows been transferred to the "small shed."

In short, what had been seen to be a succession of probabilities if the scarlatina in London districts were indeed the outcome of the milk distributed from the Hendon farm, was now established as a succession of facts.

We had thus reached the point of excluding external scarlatina, of associating the importation of particular cows into the Hendon farm with presence of scarlatina in London districts, and of connecting by a series of parallel events the milk furnished by those cows and by related cows, with the peculiarities of scarlatina prevalence among consumers of the Hendon farmer's milk. Under these circumstances, it was not judged necessary to go beyond the Hendon farm and to inquire at the two other farms that also sent milk into the London districts of South Marylebone, Hampstead, and St. Pancras, in search of the cause of scarlatina in those districts. Henceforward, until anything to the contrary should appear, an influence, competent to produce scarlatina among the consumers of the milk, was held to have operated from those cows which were received into the Hendon farm on November 15th, and the further concern of the inquiry was with the nature of such influence.

Relation of scarlatina to certain cows established.

Adhering to the design of the inquiry to proceed altogether upon the circumstantial evidence obtainable within the actual epidemic before making any comparison with former experiences, investigation of the probable nature of the influence by which the Hendon milk had operated to produce scarlatina in its consumers was now begun. After much thought about alternatives it was found necessary to accept, provisionally the belief that the influence in question, having belonged in the first instance to the 15th November cows, had belonged *to the constitution* of the cows :—was in fact some species of cow disease. And the acquisition of this influence by other cows had become so very probable, that a corresponding probability arose that any such disease in the cow had been in fact an infective disease communicable from cow to cow. The considerations of circumstance that forced these beliefs on acceptance were cogent, no alternative to them was discernible, and we could not see that feeding well and milking abundantly were reasons against the hypothesis of such disease.

Nature of morbific quality in cows.

Seeking for any exact circumstantial evidence that might possibly exist, indicative of a particular cow or cows having been at fault, the only morsel of such evidence that tendered itself was a specially promising one, but it proved disappointing. A friend of the farmer who had by favour been supplied with the "milk of a single cow," had had his family very heavily stricken by scarlatina at Hendon about the end of the first week in December. A specially fine cow had been designated for his service; but it presently appeared that the milk of that same cow, being regarded as peculiarly rich in quality, had also been taken for the children of people employed about the farm, and among these children there had been no scarlatina whatever. Thus the expectation of identifying that cow as a disease-producer was at an end, and another sort of interest in her arose. The cow was at the beginning of December living with other cows in the large shed away from the 15th November cows in the quarantine shed. It was not for some days later that the facts about this theoretical "one cow" supply were learned: the practice had certainly been less inflexible than the intention; and it was found to have been perfectly possible, to say the least, that on some occasion in early December (when the farm bailiff's back was turned) the supposed "one cow" supply had indeed been dipped out of a common churn in the large shed, in such a way that those who drank it would be in precisely the same relations to the milk service of the

farm as the consumers of the Hendon milk who were living in South Marylebone.

Notable experiment at Hendon during inquiry.

During the further study of the doings at the farm, some days of Christmas intervened, and immediately on the resumption of inquiry it was found that a most instructive but pitiful experiment had been going on at Hendon. In this Christmastide, medical men practising in the district had been called to case after case of scarlatina occurring in separate houses and obtaining the proportions of a little epidemic. The houses were at Child's Hill and elsewhere near the farm, and were occupied by people of the labouring class and the poor. The first case had dated from December 20th. Upon inquiry as to the milk supply of these families it was ascertained that they, one and all, had shortly before their invasion been exceptionally furnished with milk from the Hendon farm under circumstances as follows:—On December 15th the whole of Mr. X's milk, 63 barn gallons, mainly derived from cows in the large shed, had been returned on the farmer's hands with an intimation by the Marylebone Health Officer that he believed the milk, or some of it, to have been causing scarlatina in his district. Hereupon the farmer, though discrediting the allegation, determined not to seek for a new market for that section of his milk. The returned milk went to the pigs. For the rest, those of his customers, he said, who still desired his milk could if they chose continue to take it and be served as before, but he gave orders that the section of his produce which he regarded as being under suspicion, namely, all the milk of the large shed, should, with the exception of some to be used for pig-feeding, be thrown into a pit freshly dug in one of his fields. His instructions, however, were not completely carried out by his cowmen. It became known in the neighbourhood that milk from the farm was being thrown away, and at once a number of poor neighbours put in an appearance and begged for it. To most of them it was refused, to all those who applied to the farm bailiff; but by special grace of certain cowmen some of these neighbours received gratuitously on December 16th and subsequent days, a portion of the produce of the large shed that would otherwise, as they and the cowmen believed, have been wasted. It was among these people that scarlatina appeared about a week afterwards. It invaded some half dozen families, forming an unknown (but certainly a large) proportion of the families to whom the milk had been given, and it attacked no family to whom it was not supplied.—Conversely, upon subsequent inquiry in South Marylebone, it was found that in the period about Christmas when these Hendon families were falling ill of scarlatina new cases ceased, almost suddenly, to appear among the families supplied by the South Marylebone milk seller, and afterwards there were no fresh attacks except what were referable to spread from previous sufferers.

The experiment was complete and confirmed the inferences which had before been drawn from the distribution of scarlatina in metropolitan districts. No more of the inculpated milk was sent to London throughout the whole period of the inquiry, and of course none of it was given to neighbours after the relations of it to scarlatina at Child's Hill had been seen.

There is little more to tell of the relations that were found to exist between the Hendon cows and human scarlatina, but that little is of interest.

Observations on cow ailments.

In the last days of December after the foregoing circumstantial evidence had been, in essentials, worked out, the 15th November cows were still in the large shed: the two 4th December cows which had been put into the large shed on December 11th were still there; and the other two 4th December cows which on 11th December were placed in the middle shed, had been taken therefrom and put into the large shed, because circumstances had by this time thrown suspicion on their milk.

At this time, examination of the cows was made with a view to the detection of any, even the slightest, disease among the cows; and it was found that several in the large shed were suffering from vesicles and ulcers on the teats and udders, and that the cow most severely affected was one of those received into the farm on December 4th.

Dr. Klein, whose assistance was now invited, visited the farm with Dr. Cameron and myself on December 31st and following days, and we found that these sores on teats and udders were very general among the cows of the large shed, in the several cows being of different degrees of intensity and recency. The 15th November cows were not suffering, but on close examination of their teats and udders scars were found on two of them of a kind that satisfied us of their having shortly before suffered from the malady. Of the four 4th December cows two were suffering from the disease, one (transferred from the middle shed) had it badly, other cows in the shed had it in a more recent form. In the middle shed there were several recent cases and in the small shed two early cases of it were at this date detected.

An outside observer knowing something of cows had perceived just before Christmas certain cows in the large shed, particularly on the left-hand side of it, to be suffering from "bad quarters." He did not attach any importance to the fact, except for the unusual quantity of the ailment. The cows on the left-hand side of this shed, however, at that date included the cows imported to the farm on 15th November, and two also of those imported on 4th December.

Our belief in the existence on this farm of a constitutional disease among the cows competent to produce scarlatina among human consumers of the cows' milk was now becoming unreserved. The identity of the disease and its more obvious characters and its communicability appeared to have been demonstrated. Also, in the phenomena of the disease itself, Dr. Klein found reason for regarding it as more than a local complaint affecting the skin of the teats and udders. He regarded it as a general or constitutional disease; one that might, probably enough, be communicable from cow to cow.

Dr. Klein took with him for experimental purposes samples of milk, contents of vesicles and discharges from ulcers of two affected cows (I. and II.); and afterwards two of such cows (III. and IV.) were purchased and conveyed to Dr. Klein at the Brown institution for further observation and for pathological investigation there. He will report on the clinical features* and on the pathology of the disease.

No deference to Dr. Klein's belief, any more than the now admitted concurrences of human disease with milk consumption, weighed in any degree with the people employed about the farm to induce them to credit the notion that the health of the cows had been in question. Had not the cows eaten well and given full yield of milk, they asked, and how then could they be ill? If they had any ailment, it must be, and it was, of no consequence, and it could not have been connected with disease in man.

So they reasoned, and it was doubtless this disbelief that occasioned a little reticence among the cowmen. But one day a certain cowman who had undertaken to point out for Dr. Klein the most recent case he could find of sore teats, mentioned his having first seen such early beginning of the complaint in the case of one cow, that he very well knew, and on being requested to point out that cow he led his questioner to the large shed and showed him one of the Derbyshire cows that had come to the farm on November 15th.—It was now admitted on all hands that this cow had been the first to suffer from the malady and that she suffered very badly; that not long afterwards, other cows in the large shed and a 4th December cow in the middle shed were also found

and demonstration of cow first attacked.

* The clinical characters of the disease are the special subject of Dr. Cameron's paper, No. 8 (*b*). —G. B.

affected; and that latterly the disease was known to have spread abroad in the large shed and in the middle shed and now to be invading the small shed. To the last however the cowmen were all sure that the disease was of no possible importance whatever and could not have affected the quality of the cows' milk.

Episode.

Our discovery of this extended prevalence of the cow disease, now, on January 1st, in all the sheds of the farm, was a very disquieting circumstance, for the middle and small sheds were still furnishing milk to London consumers. We felt it necessary to advise the farm bailiff (in the temporary absence of the farmer through illhealth) at once to seek out every cow that now was or that might become affected with sore teats or udder, or any other sort of ailment; to isolate every such cow, and to keep all her milk out of the business; and to prevent cowmen employed in the tending or milking of sound cows from having anything whatever to do with the cows thus set apart. These precautions were taken after January 1st, and we had good reason to think, only just in time to prevent disaster from a repetition of the events of December. For, in gathering up the later facts concerning the various local epidemics of scarlatina in their relation to the Hendon milk service, the following facts appeared:—

(*a*.) In South Marylebone, as has been told, the new outbreaks had ceased shortly after the delivery of milk to Mr. X had ceased; and at Hendon, up to the end of December, no fresh outbreaks had occurred after those above recorded as following on the use of milk refused by Mr. X.

(*b*.) In Hampstead and St. Pancras milk districts, where Mr. Y continued to supply milk from the Hendon farm, a diminution if not a temporary cessation of fresh outbreaks had taken place about Christmas, but in the first days of January they were again becoming somewhat numerous. The reduction and the recrudescence had corresponded well with the removal of the two December 4th cows from the middle to the larger shed; and with the appearance, shortly after, of new cases of the cow-disease among the animals of the middle shed.

(*c*.) Just about the same time, in the early days of January, milk from the small shed, which had previously been without share in scarlatina production appeared, almost suddenly, to be implicated. The daughter of one of the cowmen who was employed in this shed, and who by permission took home milk from the small shed, but from no other, was attacked by scarlatina the day after her arrival in London on a visit; and, almost simultaneously with the fresh attacks among Mr. Y's customers, the customers of Mr. Z, in St. John's Wood milk district, began to suffer from scarlatina. These events corresponded to a nicety with the appearance for the first time of the cow disease among the animals of the smaller shed.

Thus the precautionary measures enjoined on the farm bailiff were not in time to prevent the beginnings of another manifestation of scarlatina in London. Their value in preventing further and more extended outbreaks in the several localities could not be estimated. For, on these fresh appearances of illness among their customers, Messrs. Y and Z at once discontinued all supplies from the Hendon farm. The whole milk of the farm was now thrown on the farmer's hands, and was given to the pigs or buried.—While this report is in preparation, I have made inquiry of Messrs. Y and Z as to any further scarlatina, peculiar to their customers, and I find that none has occurred in the milk districts of Hampstead, of St. Pancras, or of St. John's Wood since the beginning of January.

No. 8 (*b*).

Extract from a Paper to the Epidemiological Society (Session 1885–6), entitled Observations on a certain Malady occurring among Cows at a Time when the Milk produced by them disseminated Scarlet Fever; by James Cameron, M.D., Medical Officer of Health of Hendon.

I wish to lay before you a short description of a cow disease which has been the subject of investigation by Mr. Power, Dr. Klein, and myself during a recent inquiry into an outbreak of scarlet fever which occurred in the districts of St. Marylebone, St. John's Wood, Hampstead, and Hendon, amongst consumers of milk derived from a dairy farm situated within my sanitary district. Cow disease at Hendon.

* * * * * *

In entering upon a description of this cow-disease, it is necessary to note that what I have to say has not all of it been the result of personal observation. Especially is this the case as regards some of the earlier symptoms, which, of necessity, have been learnt from other persons. The account of these, therefore, though I have taken great pains to sift the statements made to me in this connexion, and, indeed believe them to be fairly accurate, must be held liable to future correction or modification. But the account I give of the course of the disease after the appearance of the eruption on the teats and udder is my own, and is, I think, less subject to qualification in the above sense. Description.

From my own observation, together with what I can learn respecting it, the disease would appear to be capable of general description as follows :

A specific contagious and infectious disease, occurring usually in the first instance amongst newly-calved cows, and capable of being communicated to healthy cows by direct inoculation of the teats with virus conveyed by the hands of the cowman after milking a diseased cow, and perhaps by discharges from the mouth, nose, and eyes of infected cows coming in contact with the manger at which other cows may feed. It has been communicated to man* by inoculation with virus from the vesicles on the teats and udder, and seemingly, it is communicable, *though perhaps in another form*, through the medium of the milk. In the cow it is characterised by general constitutional disturbance ; a short initiatory fever ; a dry, hacking cough ; sometimes quickened breathing ; sore-throat in severe cases ; discharges from the nostrils and eyes ; an eruption on the skin around the eyes ; an eruption on the hind quarters ; vesicles on the teats and udder ; alteration in the quality of the milk-secretion, and well-marked visceral lesions. The actual disease may continue in the animal for from four to six weeks, and it would seem that in some cases subsequent ill-health may last for from two to three months, or even longer, causing great emaciation and debility. It is difficult to speak of the fatality of the disease, but it would appear that sometimes, General.

* A trustworthy informant received the virus of this disease into a recent scratch upon his forefinger while milking a diseased cow. He suffered from general weakness, malaise, and loss of appetite. About four or five days after inoculation a vesicle or small blister appeared on the finger. This became broken and several others formed on the back of the hand. The whole hand and the fingers became swollen and inflamed, the inflammation extending in broad lines as far as the elbow. The general disturbance lasted a fortnight.

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Dr. Cameron's Observations

though rarely, cows have died in its course, perhaps from affections of the internal organs.

Besides attacking by preference newly-calved cows, the disease is especially prone to attack cows that have been in low condition of health before calving, and cows which have slipped their calves. In cows where, after calving, there may have been retained portions of membrane or placenta, and where the cleansing has been imperfect, with an offensive lochial discharge, it is apt to appear within the first fortnight after the calving.

Dealt with in greater detail, the phenomena* of the disease appear to be as follow :

Febrile.

Fever.—At the commencement of the illness the cow is somewhat feverish, the nose is brown and dry, the coat is rough and staring. This fever may last, in severe cases, from seven to eight days ; in slighter cases, from three or four days to a week.

Skin and mucous membranes.

Two or three days after the commencement of the fever, the skin around the eyes, in cases of severe attack of the malady, becomes puffy and swollen, and in another two or three days, *i.e.*, about the fourth to sixth day of the fever, a minute red rash, about the size of pin-heads, and slightly raised above the level of the skin, appears upon the skin around the eyeballs. The cuticle on this part usually peels off about three or four weeks after the rash appears, leaving the skin hereabouts devoid of hair.

Discharge from the Eyes and Nose.—About the time that the rash appears on the skin surrounding the eyes, a yellow mattery discharge comes from under the eyelids, and collects in the inner corner of the eye. This discharge is, in particular cases, sometimes so severe that it is necessary to cleanse it away with a sponge. In severe cases, too, the discharge may continue for some time, and is believed to be contagious. A nasal discharge of a similar nature is apt to appear about the same time, and is believed, also, to be contagious.

Cough.—A dry, husky, hacking, irritative cough, with bronchial rales and quickened breathing, frequently comes on with the initiatory fever. The cough may last, more or less, as long as the cow is ill, and the quickened breathing may continue for a fortnight, or longer in some cases.

Sore-throat.—Sore-throat is stated to occur in severe cases, especially in newly-calved cows, attended with puffiness and swelling under the jaw. It comes on with the irritative cough, and is, in some cases, so bad that the cow has to be fed with gruel. In slighter cases the sore-throat has not been particularly noticed, and may or may not have been present.

Bowels and Urine.—In very acute cases the bowels are inclined to be loose. The urine is sometimes scanty and high-coloured, and the cow loath to pass it.

Teats and udder.

Teats and Udder.—From five to seven days, more or less, after the commencement of the illness, one or more teats become enlarged, swollen to nearly double the natural size, and slightly œdematous.

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* *Mem.*: Many of the above constitutional phenomena, particularly any rise of temperature indicative of fever, were absent from the cases observed among Hendon cows by Mr. Power and Dr. Klein. In these parts of his description, Dr. Cameron is probably relying on the statements of others as to what they have observed in cases which they consider to be of the same nature as the Hendon cases.—G. B.

Dr. Cameron's Observations.

On fingering the teat there is no feeling of induration or hardness. Vesicles or bullæ next appear upon the swollen teats, and upon the udder between or near the teats. In number they range from two to four on a teat, varying in size from a pea to a horsebean, and containing at first a clear fluid. The first vesicle frequently appears between the two fore-teats, close to the abdominal vein, and is usually as large as a good-sized horse-bean. This vesicle is not preceded by a hardened papule as in cow-pox, but is in the first instance a vesicle or bulla.* These vesicles usually become rubbed and broken in milking, leaving raw sores, sometimes red, in other cases pale in colour, with raised, ulcerated-looking edges. Sometimes a few smaller accessory vesicles are formed around the margin of these ulcerated sores. The lymph from these vesicles in this stage can seemingly be conveyed by the hands of the cowman to healthy cows, and so propagate the disease by direct inoculation of their teats. Shortly after the vesicle has been broken, a brown scab forms upon the sore. These scabs may remain attached for five or six weeks, or may fall off in ten days or a fortnight, a smaller one forming afterwards. A thin, watery fluid exudes from under the scab, and the sore ultimately heals under it.

I examined the teats of several cows five or six weeks after they were attacked. The scabs then varied in size from a shilling to a florin; they were about one-eighth of an inch thick in the centre, thinning off towards the edges. On picking off some of these, the recently-healed skin was of a pearly-blue colour, with a slight tendency to bleed when the scab was forcibly detached; but there was no depression or pitting of the skin. After the vesicle had become broken and the scab formed, the swelling of the teat gradually subsided.

Distinction from other conditions.

Difference between Cow-pox, Chapped Teats, and these Vesicles.—As, in the course of our inquiry, it was strongly asserted by several people who examined the cows, that they were suffering from cow-pox, it is worth noting some of the differences between cow-pox and this disease. Both appear on the cow's teats and on the udder, at or near the bases of the teats, but in *cow-pox* a hardened *pimple* first appears, and this pimple becomes a vesicle, which, if it remains unbroken by the hands of the cowman, develops into a globular or oval acuminated *pustule*. A central depression forms in the vesicle, with raised, pearly-looking edges, with hardening round the margin, and with a distinct areola. —In the *cow-disease now in question*, there is no hard pimple preceding the vesicle and there is no subsequent formation of pustule; there is no central depression of the vesicle, no marginal induration, no areola, and when the scabs fall off there is no pitting of the skin.—It deserves mention that some persons who examined the cows affirmed that the sores on the teats were of the nature of *chaps*, caused by exposure to cold winds when the teats were moist. This was an altogether unsatisfactory explanation, because, although some of the animals stood opposite the doors (which were usually shut), many others affected with the same disease were not so exposed; and, moreover, the chapped teats, resulting from exposure to cold winds, commonly bleed in milking. These sores do not bleed in milking, unless when very roughly used.

Phases of eruption.

Skin Eruption.—I have already mentioned that one of the early symptons of the disease is puffing of the skin around the eyeballs, with a minute red eruption or rash upon it about the size of pin-heads. This was insisted on in an account given me by a competent and

* But see Dr. Klein's account of the anatomy of the eruption; particularly in the case of animal IV.—G. B.

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seemingly very accurate observer. But besides this rash an eruption appears upon the top of the hind-quarter, on one or both sides, extending, in some cases, down the outside of the leg as far as the hock, in others to the fetlock joint. I am inclined to think that the first stage of this eruption appears about the same time as the first appearance of the vesicles upon the teats; but, on account of the difficulty of seeing it upon a cow's skin, it is impossible to say so with absolute certainty. It was most difficult to find amongst the cow's hair any eruptive spots in the first stage, but on careful searching one was found upon the skin of a cow which we supposed to be in that stage. The spot was circular, about the size of a split pea, red, not raised above the level of the skin, but with a slightly thickened base. About 14 days after the commencement of the illness, this eruption on the hind-quarters has arrived at its scabbing stage, and the severity of the eruption has appeared to correspond, to some extent, with the severity of the attack, and the number of vesicles upon the teats and udder. In cows whose teats and udder showed numerous vesicles, the eruptive spots were plentiful and close together; in cases where the vesicles were few in number, and the animal evidently suffering from a slight attack of the disease, the eruption was not so well marked, but showed more in isolated spots, ranging in size from a split pea to a shilling. This eruption was confined entirely to the rump and outside of the hind quarter, there being none under the tail, on the back, or behind the ears. The skin eruption in its later stages consisted of patches of eczematous-looking crusts. When a crust was picked off, the hair came off with it, exposing a raw, moist sore, the crusts and the sores looking exactly like eczematous scabs and sores. In some cases, where the scab had been forcibly detached when newly formed, the sore looked bloody. In more advanced cases, the scab, when picked off, showed the skin healed under it, but devoid of hair. There was no pitting of the skin.

The milk of affected cows.

The Milk.—In a specific disease affecting the constitution of the cow shortly after calving, it might be expected that the milk, being an animal secretion, would be in some way affected by the disease. Specific virus circulating in the cow's blood is obviously likely to contaminate the milk produced by her, and through this medium to convey the disease to human beings. Early in the disease the milk of cows suffering in this way, if set aside for some hours, as matter of fact is apt to become ropy, or, as I have heard it described, "ropy," "slimy," or "as thick as a pudding." This condition of the milk may occur, it is said, even before the vesicles appear upon the teats and udder, or the eruption on the hind-quarters. It shows itself in milk that may have been set aside for from six to twelve hours for the cream to rise, and it ought to be looked for in all suspicious cases of cow illness. In some cases, when the cow is being milked, the first few "draughts" of the teat may bring thick or knotty milk, but afterwards there is nothing abnormal to be seen in it. In many cases there is nothing particular discernible about the milk as it comes from the cow; it flows freely, and looks exactly like ordinary milk. As the milk from this dairy farm was sent direct from the farm to the milk shop, and immediately distributed to the customers, this peculiarity would not have had time to show itself; and, further, as the cream is now usually removed by "separators," this milk would not, in all probability, have been set aside for the cream to rise. In cases where, at a dairy farm, only one or two cows are suffering from a mild attack of the disease, this ropiness might not show itself if the milk was mixed with a quantity of milk from

healthy cows, although this mixed milk might very well be capable of injuriously affecting those who consumed it.*

I believe that this ropiness of milk appears in several cow diseases. Its precise nature, and the causes which give rise to it, require careful investigation. It was particularly noticed, and described to me by several persons, as having been observed by them about three years ago, in milk supplied from another dairy farm in this district a few days before a severe outbreak of diphtheria among consumers of the milk. This ropiness of the implicated milk was the subject of much discussion at the time, and was attributed by the farmer to feeding the cows on too much clover hay. He admitted the fact of the ropiness of the milk, and took, he said, milk from each individual cow, to see, if possible, which animal gave ropy milk, but he did not set the milk aside to stand awhile, and so failed to detect the culprit. Unfortunately, in this instance, several of the cows were removed and killed before there was a chance of examining them, and so an opportunity of gaining, perhaps, important information was lost. This outbreak was the subject of special inquiry and report by Mr. Power. [*See* Medical Officer's Report to the Local Government Board for 1883, p. 42.]

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[Dr. Cameron concludes his paper to the Epidemiological Society by suggesting to farmers and cowkeepers certain precautions which they may advantageously take, while the current knowledge of the subject remains as it is.]

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* Observe in this connexion, the results obtained by Dr. Klein of inoculating milk from which teat-discharges are excluded.—G. B.

No. 8 (*c*).

App. A. No. 8 (*c*). On Milk-Scarlatina; by Dr. Klein.

Report on a Disease of Cows prevailing at a Farm from which Scarlatina had been distributed along with the Milk of Cows; by Dr. Klein, F.R.S.

In a recent report to the Board, "On certain observed relations "between scarlatina in various districts of London and Milk supplied "from a Dairy Farm at Hendon," Mr. Power has related the circumstances under which I became associated in inquiry at the farm in question; and, while briefly indicating certain provisional inferences of my own as to the nature of the malady discovered among the cows there, Mr. Power goes on to promise an account by me of the special features and pathology of the disease. This I now proceed to give.

Disease observed at Hendon Farm.

Its clinical characters:

The cows (I. and II.) which were the first subjects of my investigations had on the teats and udder several flat, irregular ulcers, varying in diameter from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch; some ulcers were more or less circular, others extended in a longitudinal direction on the teat. The ulcers were covered with a brownish or reddish-brown scab, which when scraped away left exposed a granulating slightly indurated base. The

local

margin of such ulcer was not raised, nor was there any perceptible redness of the skin around. But where I afterwards got the opportunity of watching the earlier stages (especially in animal IV.), it was noticed that a small vesicle made its appearance on a greatly swollen and red teat, in the course of a couple of days assuming the character of the above ulcers. In another cow an ulcer, about $\frac{1}{2}$-inch in diameter, was becoming covered in its central part with a scab, while at its margin vesiculation was still distinctly visible.

As a rule, *i.e.*, in most animals, the disease affected the teats, but in some there was also on the lower part of the udder here and there an ulcer. In such animals patches denuded of hair were noticed on various parts of the skin, the tail and back particularly. In these patches the epidermis was scaly, and the cutis more or less thickened. The animals looked thin, but not strikingly so, except in one or two cases of animals that had only a few weeks ago been admitted to the place, and which therefore had calved comparatively recently (see Mr. Power's report). As regards the feeding capacity of affected animals, their milking power, and their body temperature, nothing abnormal could be detected.

and constitutional.

Two animals (to be referred to as cow III. and cow IV.) became the special subjects of study after they had been removed from the farm to the stables of the Brown Institution.

The temperatures (Centigrade degrees) of cow III. were as follows:—

	Morning Temp.	Evening Temp.
January 4	38·8°	38·7°
„ 5	38·9	38·9
„ 6	38·8	38·3
„ 7	38·9	—
„ 8	39	39
„ 9	38·8	38·7

The temperature afterwards remained as above without alteration.

The temperatures of cow IV. were:—

January 6	38·4	38·3
„ 7	38·7	—
„ 8	38·4	38·3
„ 9	38·6	38·5

In animal III. the ulcers were present, and on January 4 were at their full development and covered with crusts. They gradually died away, and subsequently healed up by January 10, leaving, however, a whitish indistinct flat scar.

When this animal was received there were noticed on its coat several patches where the hair was gone, and the epidermis was rough and scaly.

Animal IV. when received showed several scabs in the skin of the back; it had also muco-sanguineous discharge from the vagina (the animal was in the third month of pregnancy), and redness and excoriation of the mucous membrane of the vagina. One teat, which was much swollen and inflamed, presented in several places brownish crusts. These when taken off left an infiltrated firm sore, from which, when squeezed, a thickish lymph oozed out. Similar crusts were found on other teats and on the udder. The greatest development of the sores in this cow was on January 7. On January 9 the sores were decreasing; the animal was then killed.

Post-mortem characters.

On opening the chest it was found that both lungs exhibited in the upper posterior lobes numerous petechiæ under the pulmonary pleura; the peripheral lobules of these parts being much congested. There were numerous adhesions by recent soft lymph between the lower lobes of the lung and the costal pleura, particularly laterally. In the liver there were several reddish streaks and patches, reaching from the surface of the organ to a depth of about $\frac{1}{4}$ of an inch. In these patches the liver tissue was much softened. The spleen and kidneys, with exception of slight congestion, appeared normal. In the placenta there were numerous petechiæ.

Cow III. was killed on March 12. For some days previously the animal had been getting very thin, notwithstanding its ravenous and excessive eating. On post-mortem examination the following appearances were found:—

In the lungs there were numerous lobules, especially in the peripheral parts, which showed great congestion; there were in addition pleural adhesions; the cortex of the kidney was congested, but its medulla was pale.

Direct inoculation into calves

Experiments were now made with the matter of the ulcers, with a view of ascertaining whether or not the disease was transmissible to other animals.

On January 7, when the ulcers of cow IV. had reached their maximum development, I took scrapings from some of the ulcers on the udder and teats, having first removed the crust, and inoculated in several places the skin of groin and inside of ear of two calves (1 and 2.) For inoculation a superficial small incision (not longer than about $\frac{1}{4}$-inch) was made, passing in an oblique direction through the superficial part of the corium, and into this pouch a particle of the scraping was rubbed.

On January 9, with scraping of ulcers of the cow before she was killed, I inoculated two calves (3, 4), introducing the matter as before into the corium of the groin and of the inside of ear.

Calves 1 and 2 showed during the first three days after insertion of the matter no change at the seat of inoculation.

Four days after inoculation:—There was in calf 1 one place in the groin which promised to become an ulcer. Calf 2 showed on the ear one promising place, the other places of inoculation having nearly healed.—At the same distance of time after inoculation calf 3 showed two promising places on the ear, and calf 4 showed two promising places in both groin and ear. Calf 3 also showed a kind of vesiculation at the margin of the spot inoculated and commencing formation of a crust in

the centre. What I call promising places of inoculation were spots that had become swollen and tender, the other and not promising places were spots that seemed healing or were already healed and dry.

On the sixth day :—Calf 1 showed four successful places in the groin ; the places had become swollen and enlarged with imperfect vesiculation at the margin and formation of crust in the centre.—Calf 3 had four successful places on the ear ; and calf 4 had the same number in the groin.

On the seventh day :—In calf 1 all places except one in the groin had nearly disappeared. This place was now a distinct ulcer covered with a crust, on removing which a granulating infiltrated base was exposed. In calf 2 all places of inoculation were decreasing, covered with small scabs, easily detached.—In calf 3 the sores on the ear had enlarged to about $\frac{1}{2}$-inch in breadth, each of them covered in their whole exten by a brownish crust. In calf 4 all except one place on ear were healing.

On the eleventh day :—Calf 1 had still one ulcer in groin not yet healing. Calf 2 had one ulcer on ear not quite healed up.—Calf 3 had four big ulcers still progressing ; crusts thick, and corium much indurated. Calf 4 had one ulcer on ear much diminished in size.

By the eighteenth day :—The ulcerations in calf 3 (one ulcer nad been cut out for microscopic examination) had all healed up and become converted into flat scars. In the other animals the healing was completed at an earlier date.

Simultaneously with the above experiments several inoculations with materials of the ulcer of cow No. IV. had been made into the skin of the groin of ten guinea-pigs and of three dogs. In the guinea-pigs no result was obtained; but in one of the dogs one place of inoculation appeared swollen and inflamed on the third day. On the fifth day this place was an oblong ulcer of about $\frac{1}{4}$-inch in diameter ; the margin was red and swollen, but the centre was without crust (the animal had been frequently seen to lick it). On the seventh day the ulcer was much smaller, and it had nearly healed up by the tenth day.

Summary of results.

From these experiments there can be no doubt whatever that by inoculating a particle of matter from the sores of an affected cow a positive result has been obtained in all four calves. In calf 3 this result was best and most striking. After an incubation of about three days the places of inoculation became swollen, tender, and spreading ; on the fifth to the sixth day the change was distinct, the successful places having become sores ; in the marginal part showing vesiculation, and in the centre formation of crusts. The sore enlarged during the next few days, and on removing the crust a raw surface was exposed, the corium itself being found infiltrated. According to the intensity of the process the retrogressive change sets in later or sooner ; in slight cases the healing begins about the ninth or tenth day, in severe cases (calf 3) not before the end of the second week.

Having thus demonstrated this disease of the cow to be directly communicable from animal to animal, I set to work to study its minute anatomy. (*See Plates IX.–XVIII., which follow this paper.*)

Minute anatomy of the disease : of skin ulcers, *Figures* 12-13.

The microscopic examination of fine sections through the ulcer of the cow shows the following conditions :

The corium throughout the whole extent of the ulcer is infiltrated with round cells. This infiltration, though densest in the central portions of the ulcer, is sufficiently pronounced even in the peripheral parts, but it gradually fades away on passing from the ulcer to the normal skin. The infiltration in the deeper parts of the corium is limited to the vascular branches, but in the superficial parts is more diffuse, the

papillæ becoming at the same time thicker. This thickening of the papillæ fades off towards the periphery of the ulcer.—The most noteworthy changes are, however, present in the epithelium. In the peripheral portions of the diseased part there are present in the superficial layers of the stratum Malpighii close to the stratum lucidum, as also in the stratum lucidum itself, numerous cavities of different sizes. *Figures* 12-13. These cavities lie closely side by side; the most superficial ones are either covered by the stratum lucidum or extend between the layers of this stratum. The former cavities descend into the depth of the epithelium; at the very margin of the diseased part they are smallest, and they do not in depth comprise more than the superficial third of the stratum Malpighii. They enlarge in depth gradually as we pass from the periphery of the ulcer towards its centre; at its very centre they *Figure* 11. involve the whole thickness of the stratum Malpighii. At the same time it is to be noticed that, at the marginal parts, the cavities, although closely placed side by side, are well separated from one another by thicker or thinner trabeculæ composed of epithelium; while at or near the centre of the ulcer these trabeculæ get destroyed, and the cavities become confluent, and the covering layers of the cuticle having here also given way, their contents extend on to the free surface of the ulcer. These contents, which go to form what has been above mentioned as the crust, spread thus gradually over the surface, not only *Figure* 13. of the centre, where the stratum lucidum has become lost, but also over the rest of the ulcer. In the marginal positions, *i.e.*, where the superficial layers of the cuticle are still present as cover of the above cavities, this layer (*i.e.*, the stratum lucidum) separates the contents of the cavities from the crust. The contents of these cavities consist (*a*) of an albuminous fluid looking, in hardened sections, uniformly granular or containing also fibrinous threads; (*b*) of a few red blood corpuscles; and (*c*) chiefly of round cells or pus cells, the nuclei of which, near to and on the surface, gradually break up into amorphous granular matter.

In the central parts of the ulcer the whole exudation undergoes degeneration into débris, and not only in its superficial, but also in its deeper portions. While some cavities contain very few cells and are filled chiefly with albuminous fluid (granular or fibrinous), others are almost entirely filled with pus cells closely packed together. In the papillæ near the cavities the blood vessels are engorged and there is also escape of red blood discs.

On a careful examination it is evident that the origin of these cavities is in enlargement of and exudation into the tissue of the papillæ, but only of those portions nearest to the stratum lucidum, and from hence arises formation of cavities in the cuticle. The whole anatomical details of the distribution and arrangement of these cavities recall vividly the conditions observed in the vesicles of cow pock and of sheep pock, and on comparing under a low power of the microscope a section through a sheep pock with a section through the ulcer of the cow now under consideration, the similarity is very striking indeed.

There are, however, anatomical differences between the two diseases. The infiltration of the corium is slighter in the cow ulcer than in the sheep pock, and in the cow ulcer the cavities form in a more superficial stratum of the epidermis.

There is in the disease we are now considering a good deal of infiltration of the epithelium by round cells derived from the cavities, not only into the stratum Malpighii, but also, and particularly in the marginal parts, into the cuticle; the round cells burrowing in great *Figure* 12.

App. A. No. 8 (*c*). numbers between the scales of this stratum, and ultimately reaching the free surface to join those of the crust.

On Milk-Scarlatina; by Dr. Klein.

Fine sections made through the ulcer artificially induced by inoculation in the ear of calf 3, proved its complete identity in anatomical

Figure 14. respects with the ulcer in the cow. The infiltration of the superficial corium; the formation of cavities, filled with exudation cells and fluid, in the superficial layers of the epithelium, particularly between the layers of the cuticle; the final destruction in the centre of the ulcer of the covering cuticle; and the extension of the exudation over the free surface to form here the crust, are the same in both instances.

Microscopic examination of the internal organs of cow IV. revealed facts as follow:—

in internal organs.

Figure 17. *In the lung.*—Sections made through the portions above mentioned as containing much congested lobules, show not only great congestion of the blood vessels, large and small, but a large amount of hæmorrhage; blood in substance being present in the air vesicles and infundibula, in the lymph spaces of the interlobular septa, and in the tissue and lymphatics of the pleura. In the latter membrane numerous diplococci are to be met with. Here and there the same diplococci occur in the alveolar wall and in the tissue of the interlobular septa.

Figures 18-19. Sections through *the liver* show a great deal of change. Under the capsule, as well as in the substance of the liver, there occur, in connection with the interlobular branches of the portal vein, larger and smaller foci of inflammation, consisting in the presence of numerous round cells. Some of these foci are several millimetres in diameter, others are very small. From the interlobular tissue the inflammation extends into the lobules between the liver cells. The liver cells of these lobules involved in the inflammatory process are swollen up, and many of them are undergoing disintegration. In some of these foci, particularly those situated in the vicinity of the capsule, the round cells are so much crowded that given foci look almost like miliary abcesses. The blood vessels are much distended and filled with blood.

Numerous diplococci and short coccus-chains occur in the parts surrounding the inflammatory foci. These are particularly numerous near the capsule in the vicinity of inflamed parts.

Figure 20. Sections through the *kidney* showed well-marked glomerulo-nephritis; infiltration of the sheath of the cortical arterioles with numerous round cells; the epithelium of the convoluted tubules swollen, opaque, and in many places disintegrating.

Figures 16 & 21. The lungs and kidney of cow III. showed on microscopic examination the same appearances as in cow IV.; in addition there was a good deal of round-cell-infiltration in the wall of the infundibula and bronchi in the lung, and around the cortical arterioles in the kidney. In the bloodclots filling the alveoli and small bronchi of the lung there were

Figure 16. present larger and smaller clumps of micrococci.

Search was now made for micro-organisms inhabiting the tissues of the ulcer of the cow, with a view of ascertaining what were present, and afterwards whether any single kind of those found had the power, when dissociated from the diseased tissues and inoculated into healthy animals, of transferring the disease.

Micro-organisms discovered in the ulcer, Removing the crust, scraping off the most superficial layer, then squeezing the ulcer so as to collect a droplet of lymph, I spread it in thin films on cover-glasses, and dried, stained, and mounted the several specimens in the usual manner. Such a specimen, examined under the microscope, revealed a number of red blood discs, mixed up with large numbers of pus cells, each of which contained two, three, or four small

nuclei and remnants of epithelial cells. Amongst the pus cells numerous dumb-bells of micrococci (or diplococci), and a few short chains of the same, were met with. In size, these micro-organisms do not differ from those described in connection with foot-and-mouth disease. In many sections—stained in fuchsin, or in methyl blue, or in gentian violet—through the diseased tissue of the cow, as well as that of calf 3, there were found the same diplococci and chains in the contents of the superficial cavities, as well as in the depth of the epithelium. In the latter stratum they were met with abundantly throughout the whole extent of the marginal portion of the ulcer, but not beyond it. In the superficial parts, namely, in the contents of the cavities in the stratum lucidum, the same chains were to be found, provided the pus cells were not too closely packed. They were very numerous in the tissue of the crust, and also in the superficial central portions of the ulcer that had undergone degenerate change. There occurred also in the crust and in the necrotic parts of the ulcer numerous clumps or zooglea of micrococci; but these micrococci are not to be confounded with the chains of streptococci to be presently described, nor yet with those streptococci which are found occurring singly.

have special characters when grown in nutritive media.

From the deeper parts of an ulcer of cow IV. material was obtained with which tubes containing either solid nutritive gelatine, or Agar-Agar mixture, were inoculated. After some days, and in both media, a micrococcus appeared, the growth of which was extremely characteristic. These are its characters, in the nutritive gelatine: after 3—6 days incubation at 20° C., the growth made its appearance at the point or line of inoculation, in the form of small points or granules, whitish in colour and tolerably closely placed. During the next few days their number and size increased. At the end of a fortnight the line of inoculation was visible as a streak of whitish granules or droplets, some large others small, more or less closely placed. On the surface of the gelatine the growth, like a film of granules, spreads slowly in breadth, but even after months remains small. When inoculated into the depth of the gelatine, the channel of inoculation becomes visible as a whitish streak, made up of smaller and larger droplets. The gelatine is not liquefied by the growth. The same characters are assumed by the growth in Agar-Agar mixture, and in solid serum. The general aspect of the growth in gelatine, in Agar-Agar, and in serum, is very similar to that presented by the *streptococcus* of foot-and-mouth disease (see my report of this year upon that malady*), but with this difference, namely, that in gelatine tubes the streptococcus of foot-and-mouth disease is a little faster in its growth, and its component granules are a little more distant. Nevertheless, I have tubes of both kinds of organisms in gelatine and in Agar-Agar—tubes which cannot be from their general appearances easily distinguished. In faintly alkaline broth, or in broth and peptone, the micrococcus of the cow ulcers grows readily, and in the same manner as that of foot-and-mouth disease. But there is one test by which the two kinds of organism can be very readily distinguished: the streptococcus of foot-and-mouth disease, when grown in milk, does not affect the fluid character of the milk, whereas milk inoculated with the organism obtained from the cow's ulcer will, if kept for two days in the incubator at 35° C., have been turned completely solid. This difference is a very striking difference, and a few days' growth in milk suffices for distinguishing without fail between the two.

Figure 24 (2 & 4)

Figure 24 (5).

Figure 23 (1 & 3)

Streptococcus.

Speciality of growth in milk

* App. B., No. 1, of present volume. Compare also Plate VIII. with XVII.

App. A. No. 8 (*c*)

On Milk-Scarlatina; by Dr. Klein.

Figures 22 & 23.

The microscopic examination of a culture in broth peptone, in gelatine, or in Agar-Agar mixture shows that the growth consists of spherical micrococci, arranged as diplococci, and as shorter and longer straight, wavy, or curved chains—streptococcus,—these latter sometimes of great length. As regards the shape of the micrococci, the mode of their division, the branchings of the chains, the presence here and there in the chain of a large element amongst the smaller ones, the organisms of the ulcers hardly differ from the description which I am preparing of the streptococcus of foot-and-mouth disease. The elements of a coccus-chain of the foot-and-mouth micro-organism are, however, smaller than those of the disease under consideration.

The streptococcus chains of a growth in broth are short during the first few days; but later on, when the growth settles down more into the deeper parts of the broth, the chains become of great length. So also in Agar-Agar tubes of one to two or more weeks' incubation.

appears absent from udder-milk.

A curious fact, to which importance must provisionally attach, is this: In a cow having several of the ulcers on the teats, the fingers of the milker pressing over the ulcers would constantly rub off from the latter particles of matter, and the fingers and the teat being kept moist, this matter would easily mix with the milk as it passes from the teat. To learn whether the milk *while in the udder* contained the streptococci, the following experiment was made: A teat free of any ulcer was milked so as to obtain a few ounces of milk, and from this milk a large number of gelatine and Agar-Agar tubes were inoculated; a second teat of the same cow, affected by an extensive ulcer, was milked to the same extent, and from the milk thus obtained a large number of other gelatine and Agar-Agar tubes were inoculated. In the first series no single tube showed the growth of the above-described streptococcus, whereas in the second series one gelatine tube and one Agar-Agar tube were found to develop the typical growth of the streptococcus. We cannot draw any certain inference from this one observation, but evidently the experiment deserves repetition.

Effects of inoculating its sub-cultures.

With a cultivation (a third sub-culture) in Agar-Agar mixture of this streptococcus, I, on February 1, inoculated subcutaneously in the groin two calves (5 and 6). On February 27 calf 6 was found dead. The subcutaneous tissue at and for some distance around the seat of inoculation showed much effusion, and the inguinal glands were swollen and red. There was peritonitis, with sanguineous exudation, congestion, and hæmorrhagic spots in omentum and in the serous coat of the stomach. The spleen appeared small and its capsule thickened. The liver was greatly congested. Kidneys were large and much congested. The ileum was much congested in its mucous membrane, and the epithelium detached in flakes. The mesenteric glands belonging to the ileum were greatly enlarged and hyperæmic. Both lungs were congested, the superficial lobules showed so much congestion that they looked almost solid, and were of a deep red colour. A few petechiæ under the pleura. Bronchial glands enlarged and congested. There was pericarditis, and the heart was distended by and filled with coagulated blood. The organs of the throat were found much congested. The hairy parts of the skin were not examined.

Calf 5 showed on March 7, around the nostrils and lips of the mouth, and on hard palate and gums, numerous irregularly outlined patches not raised above the level of the skin. These patches had a discoloured, brownish, very slightly raised margin, and a paler centre; they were round or irregular, some as small as $\frac{1}{8}$ of an inch, others four to six times larger. The animal was killed on March 8. On

post-mortem examination the following appearances were noted: Congestion of some of the peripheral lobules in both lungs; the pleura pulmonalis slightly opaque, numerous soft lymph adhesions between it and the costal pleura; in the spleen several hæmorrhagic patches under the capsule in the shape of bullæ filled with semi-congealed blood; spleen pulp softened and very congested; kidney congested; organs of the throat congested.

There can then be no doubt that a definite disease has been produced in both animals, of which the affection of the lungs is a conspicuous feature, and coincides with, though more pronounced than, the lung disease noticed in cow IV.

to produce a specific disease,

In calf 5 there was, in addition, the disease of the skin and in the mouth, which, as the microscopic examination proved, is in a certain degree similar to the disease in cow IV. and calf 3. More in detail, this is what is found as regards the skin: The tissue of the papillæ and of the superficial corium is infiltrated with round cells, and the blood vessels of the papillæ are distended and filled with blood. In their peripheral portions, their most superficial parts, the papillæ are very much distended by extravasated blood and round cells;—in fact the first rudiments of cavities are forming in them. The same condition, but more pronounced, obtains in the cuticle, where between its layers there are present small cavities filled with blood and round cells or only fluid and a few round cells. There is, in addition to this, a general infiltration with round cells of the layers of the cuticle. The brownish reddish colour of the marginal parts is due to this condition. In the central part the cuticle is loosened by the formation of such cavities containing fluid and a few round cells; by this its layers were separated and ultimately detached. In the cavities of the cuticle occur very fine diplococci and chains. So also in the infiltrated and enlarged papillæ, and in the deeper layers of the epithelium in the whole extent of the diseased skin, diplococci and short chains are present.

Figure 15.

having characters in skin and elsewhere:

In neither of these cases of subcutaneous inoculation was there found any rent or breakage of the stratum Malpighii, *i.e.*, no real ulcer. The anatomical features here described in many respects resemble the lesion of the skin in human scarlatina (see my report for 1876). I did not, unfortunately, look at other (the hairy) parts of the skin to see whether there were any such patches in this calf. (Some observations on the kidney of calf 5 are noted in the sequel.)

Examination of the organs of calf 6:

(*a.*) *The lung.*—Congestion of all blood vessels, large and small. Transudation of fluid and hæmorrhage into the alveolar cavities of part of some lobules of the lung while the rest of the alveolar cavities are collapsed, the capillaries around them very much congested; infiltration with leucocytes of the interlobular septa, extending also into the interalveolar septa. In some of the lobules next to the pleura the engorgement of the capillaries is extremely great, blood *en masse* filling the alveoli to the extent of producing a state of red hepatisation. The pleura itself is thickened by exudation of fluid and leucocytes. The bronchi do not show any distinct alteration. Numerous diplococci and a few chains are met with in the pleura and in the congested parts of the lobules, in the alveolar wall, and in those alveolar cavities which contain exudation and blood. The bronchial glands show great changes: the capsule and septa being much thickened by exudation and leucocytes; the lymph-vessels everywhere filled with round cells; the tissue of the follicles and medulla much swollen.

(*b.*) *The liver* shows extreme congestion of all vessels in all parts, inter- and intralobular. The liver cells are opaque, granular, and atrophic.

(c.) *The ileum.*—The epithelium of the surface detached and gone; the epithelium of the Lieberkühn follicles loosened, and in most places detached; the mucosa shows great congestion and infiltration; in the superficial layers the villi show hæmorrhage, the tissue being filled with blood corpuscles, fibrin, and leucocytes; and in many spots the superficial layers of the mucosa are necrotic.

The Peyer's glands are much swollen and inflamed; the central portion of their follicles are breaking down.

Micrococci and bacilli pervade everywhere the tissue of the mucosa. The mesenteric glands in relation with the ileum have their capsules, septa, follicles, and medullary cylinders much congested and inflamed.

in kidney.

(d.) *The kidney.*—The changes in this organ are highly interesting, since they completely coincide with those in acute scarlatinal nephritis in man: great congestion of the cortex, leading in some parts to hæmorrhage into the parenchyma; glomerulo-nephritis with exudation of albuminous fluid and blood into the cavities of the Malpighian corpuscles; granular or opaque swelling of the epithelium of the uriniferous (convoluted) tubules, with degeneration into granular débris of many of the epithelial cells; miliary foci of aggregations of round cells around small blood vessels; congestion of the medulla.

[The kidney of calf 5 was also examined microscopically, and the changes were exactly the same as those found in the kidney of calf 6, viz., congestion of the glomeruli, glomerulo-nephritis, transudation of albuminous fluid and red blood corpuscles into the cavity of Bowman's capsule; opaque swelling of the epithelium of the convoluted tubules, granular disintegration of the epithelium in many places; infiltration with round cells around some arterioles of the cortex; and congestion of the medulla.]

(e.) *The heart's blood* was examined for organisms, and in it, by the staining with Weigert's gentian violet, a few diplococci and a few chains could be distinctly detected.

Cultivations were made with this blood in tubes containing Agar-Agar mixture, and a growth of the streptococcus was obtained in all respects identical with the streptococcus that had been employed for inoculation of this animal.

Relation of disease with streptococci.

In view of the whole of this evidence, I consider it conclusively established that this streptococcus is identical with the virus of the cow disease.

Its strong resemblances to human scarlatina.

We have, then, inoculated subcutaneously with sub-cultures of the streptococcus these two animals, calves 5 and 6, with the result of producing a general disease, which in many respects bears a close resemblance to human scarlatina. The minute anatomical characters of the eruption on the skin around the nostrils and mouth in calf 5 is of much significance in this connection, as also is the disease in the liver in both animals, and above all, the disease in the kidney. This latter organ corresponds so closely with a kidney of an acute case of human scarlatina, that sections made of the one and compared with those of the other, of which I preserved a large collection from my former investigation into the anatomy of human scarlatina (see Medical Officer's Report for 1876), show no difference whatever.*

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* Referring to the commencement made in 1882 of investigation of the results producible in the cow by inoculation with the material of human scarlatina, see p. 67 of report of that year, I would propose that this study be extended without loss of time

The outcome of the investigation thus far, and it is of importance until further differentiated observations shall have been made, may be stated thus:—By inoculating the virus directly taken from the local disease (the ulcer on the teats) of the cow into the corium of the calf the same local disease is produced, namely, a change in the skin, which commences as a congestion of the papillæ and corium, and an exudation of fluid and leucocytes. This leads in the superficial parts of the epidermis to the formation of cavities, which, enlarging and extending and opening on to the surface and extending into the depth, ultimately lead to the formation of an ulcer. But the virus, in the form of an artificial cultivation of the streptococcus derived from the above ulcer of the cow, when inoculated into the subcutaneous tissue, that is, when introduced almost directly into the vascular system (for all matter injected subcutaneously is easily absorbed by the lymphatics and carried into the blood system) sets up a general disease resembling to a considerable degree in its anatomical features human scarlatina.

Furthermore, as respects the concern that cow's milk may have in the communication of disease—the consideration which led to the present investigations—we have some facts which appear to me to afford very suggestive indications for further pathological study. As I have pointed out on a previous page, it would seem that the milk pure does not contain the organism, but (whether or not this observation be confirmed) the milk during the act of milking is pretty sure to become contaminated by the fingers of the milker bringing down into the milk particles from the ulceration on the teat. The organism contained in these particles would find in the milk a good medium in which to multiply. Such milk would then practically correspond to an artificial culture of the streptococcus, such as we have found capable of setting up a general disease, when inoculated subcutaneously into calves. It is true we have as yet no experience of the inoculation of a known milk sub-culture into the human subject, but in the case of calves, we have learnt that the general disease resulting from inoculation of an Agar-Agar sub-culture had characters closely allied to, if not identical with, human scarlatina. Then, feeding of animals with the cultures has not yet been tried, so that at present we are without information as to the characters of any disease that may be produced in calves by that means; whether or not calves fed with milk sub-culture of our streptococci exhibit the same pathological states as we have found to be produced by inoculation of calves with an artificial culture,—states that bear so marked a resemblance to those of scarlatina in the human subject. In order completely to understand these and other relations, more experiments are required, and these I hope soon to have an opportunity of making.

Until I am in a position to state at greater length the peculiarities of the infective phenomena of the disease under consideration, I refrain from further comment on its various interesting and promising aspects.

[*The following drawings* (*Plates IX.—XVIII., figures* 11—24) *relating to the Hendon Cow Disease, have by an error been numbered in sequence to some other drawings which appear on later pages of the present volume.*]

HENDON COW DISEASE.

PLATE IX.

FIG. 11.

Vertical section through the ulcer on the teat of cow IV. Magnif. power about 30.

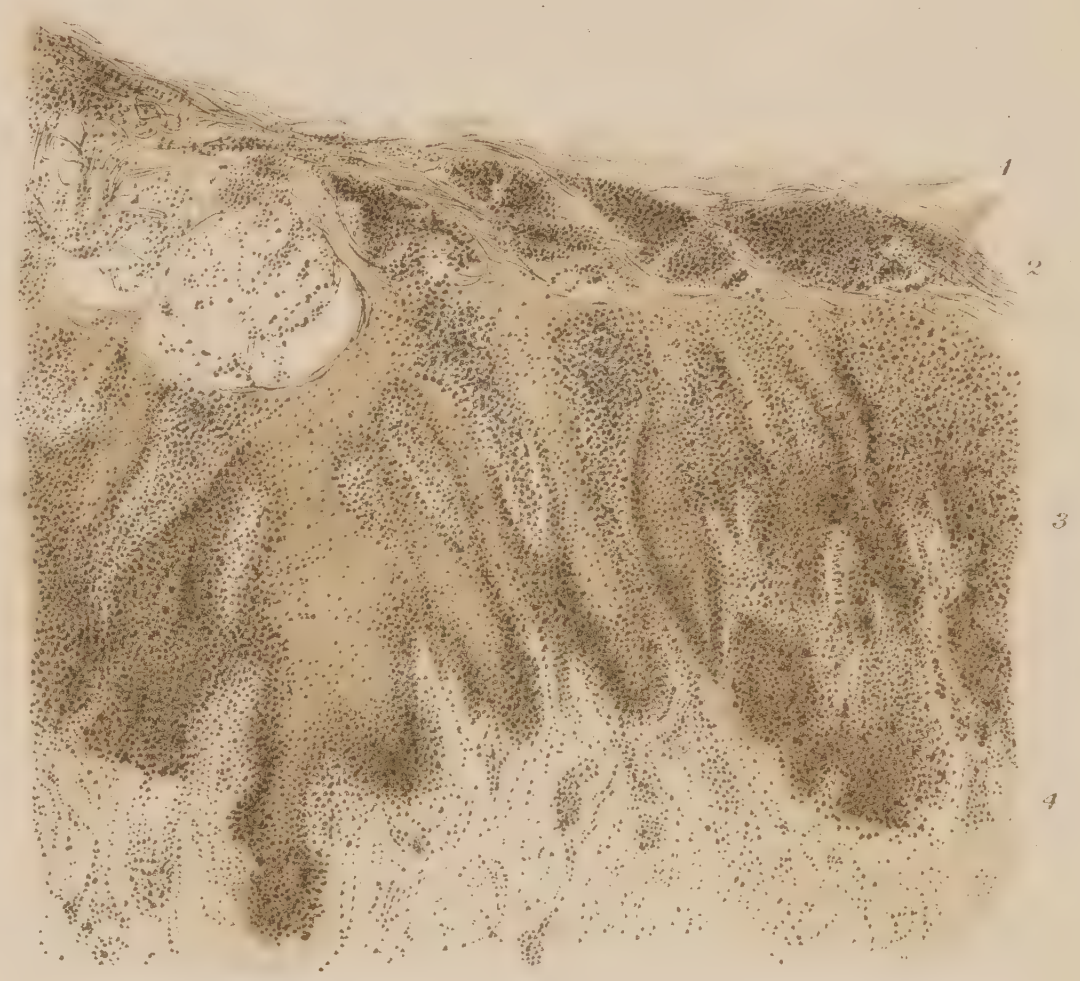
1. Horny layer.
2. Superficial layer of the stratum Malpighii, containing cavities.
3. Deep layer of the stratum Malpighii and papillæ.
4. The centre of the ulcer, where the whole of the stratum Malpighii has become broken or destroyed.

Fig 11.

J.H.Lapidge del.

Dangerfield, Lith. 22, Bedford St. Covent Garden

Fig. 12.



HENDON COW DISEASE.

PLATE X.

Fig. 12.

Vertical section through the peripheral part of an ulcer on the teat of cow IV. Magnif. power about 90.

1. Horny layer.
2. Superficial layer of the stratum Malpighii, containing cavities filled with round-cells.
3. Deep layer of the stratum Malpighii and papillæ, infiltrated with round-cells.
4. Superficial corium, infiltrated with round-cells.

HENDON COW DISEASE.

PLATE XI.

Fig. 13.

From a vertical section through the periphery of an ulcer on the udder of cow IV. Magnif. power about 100.

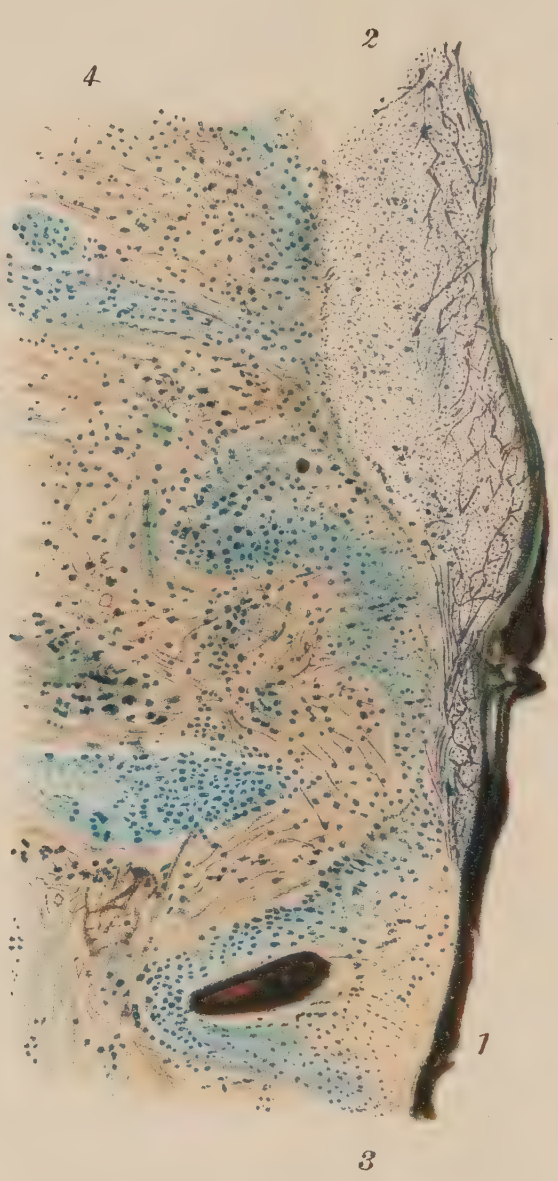
1. Horny layer.
2. Cavities in the superficial layer of the stratum Malpighii.
3. Scab, formed of coagulated lymph.
4. Deep layer of the stratum Malpighii and papillæ.
5. Superficial corium, infiltrated with round-cells.

Fig. 13.

H. Lapidge del.

Dangerfield, Lith. 22, Bedford St Covent Garden.

Fig 14



M.H. Lapidge del.

Dangerfield, Lith. 22, Bedford St. Covent Garden.

HENDON COW DISEASE.

PLATE XII.

FIG. 14.

Vertical section through the periphery of an ulcer produced on the ear of a calf by inoculation with matter taken from the ulcer on the teat of cow IV. Magnif. power about 80.

1. Horny layer.
2. Cavity, in the superficial layer of the stratum Malpighii, filled with coagulated lymph.
3. Deep layer of the stratum Malpighii.
4. Superficial corium infiltrated with round-cells.

HENDON COW DISEASE.

PLATE XIII.

Fig. 15.

Vertical section through the peripheral part of the eruption, produced on the lip of mouth of a calf, by subcutaneous inoculation into the groin of matter from an artificial cultivation of the streptococcus. Magnif. power about 40.

1. Horny layer.
2. The margin of the eruption, indicated by small cavities in the superficial layer of the stratum Malpighii.
3. The superficial layers of the stratum Malpighii becoming separated, loosened, and desquamating.
4. The deep layer of the stratum Malpighii and papillæ, latter much infiltrated with round-cells, particularly at or near the margin of the eruption.
5. The superficial corium much infiltrated.

The appearances shown in this figure 15, which is an accurate representation of the specimen, are identical in all respects with those of a specimen of human scarlatinal skin-eruption in the stage of desquamation.

Fig. 15.

J. Lapidge, del.

Fig. 16. 1

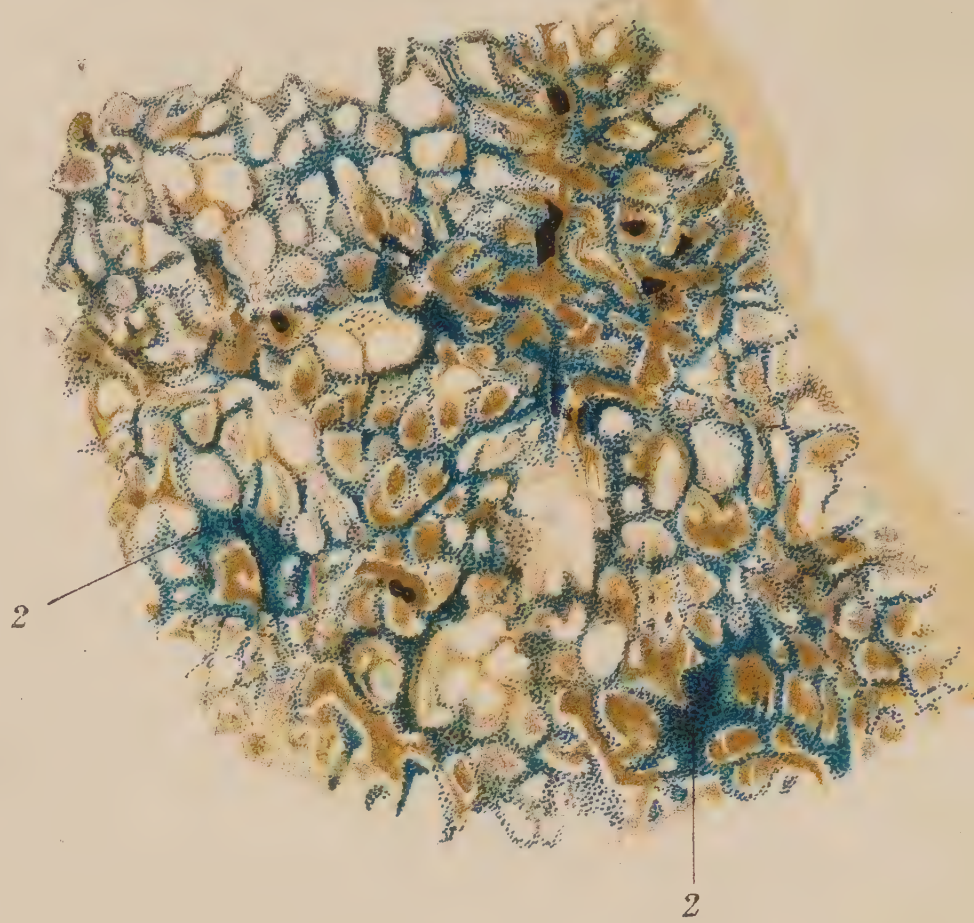
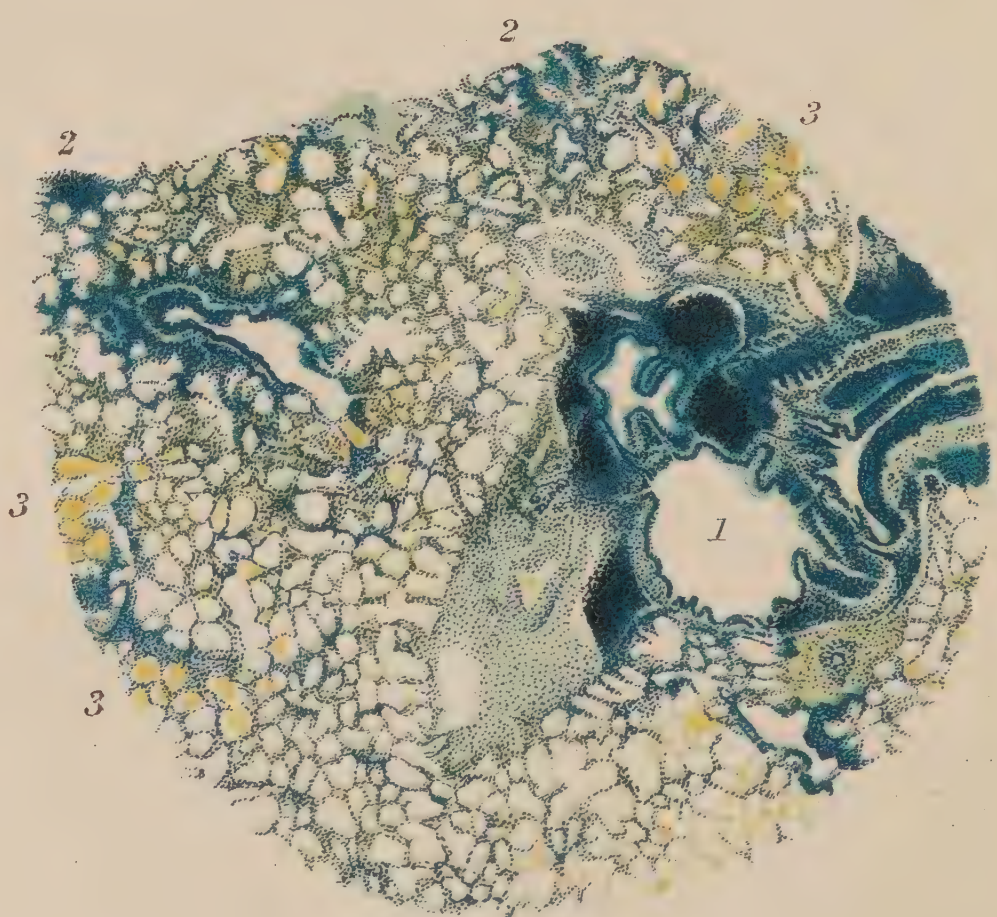


Fig. 17.



M.H. Lapidge, del. Fred^k Dangerfield, Lithographer, London. 12308.

HENDON COW DISEASE.

PLATE XIV.

Fig. 16.

From a section through the peripheral portion of the upper lobe of the lung of cow III. Magnif. power about 48.

The alveoli and many infundibula are filled with blood-clot, tinted yellowish-brown. In some of these blood-clots are seen deeply-stained patches ; these are masses of micrococci.

1. Part of the pulmonary pleura.
2. Infiltration of the tissue with round-cells.

Fig. 17.

From a section through the lung of cow IV. Magnif. power about 40.

1. Bronchi in section, large masses of lymphoid tissue in their wall.
2. Diffuse infiltration of the lung tissue with round-cells.
3. Alveoli (stained yellow) filled with blood.

HENDON COW DISEASE.

PLATE XV.

Fig. 18.

From a vertical section through the liver of cow IV. Magnif. power about 40.

1. Peritoneal surface of the liver.

2 and 3. Large accumulations of round-cells amounting almost to miliary abscesses, chiefly round the branches of the portal vein.

Fig. 19.

The lowest portion of the previous figure, more highly magnified; about 100.

1. Accumulation of round-cells in the interlobular tissue.
2. Central vein of a lobule; numerous round-cells extend from the interlobular tissue towards the central vein.

The lighter large dots indicate the nuclei of the liver cells.

Fig. 18.

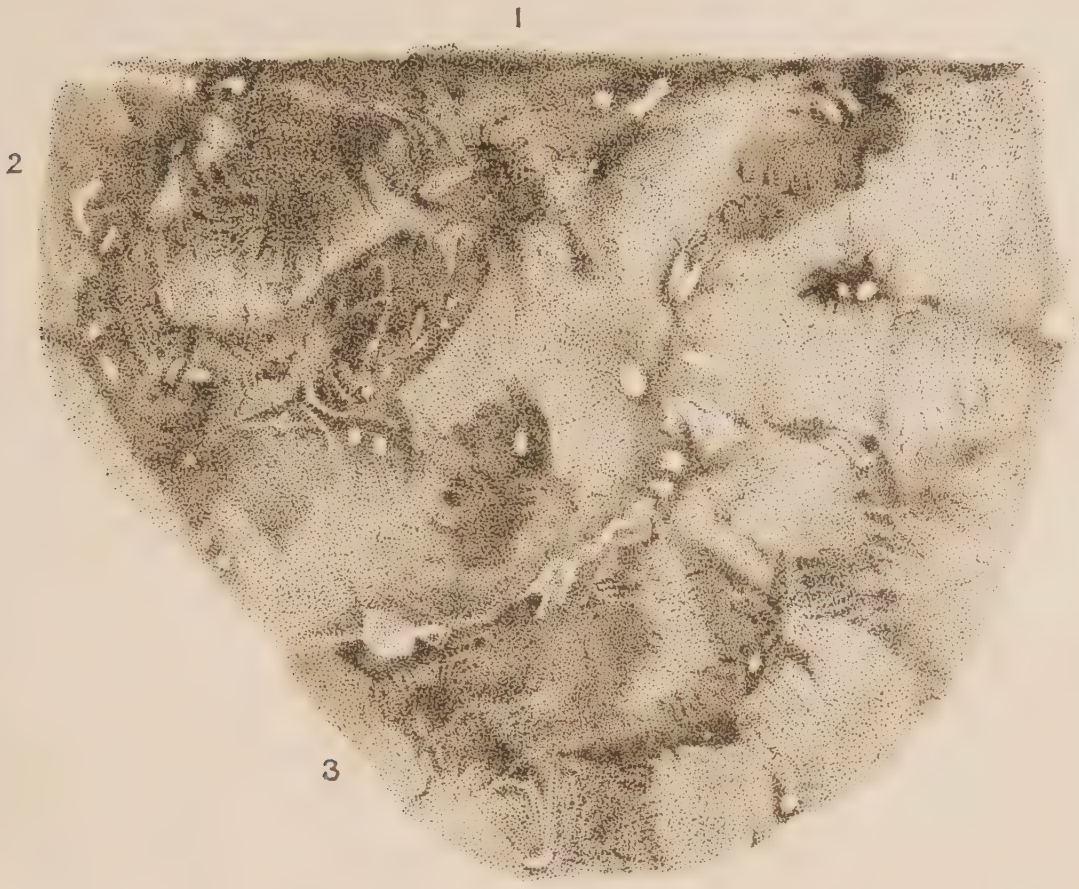


Fig. 19.

Fig. 20.

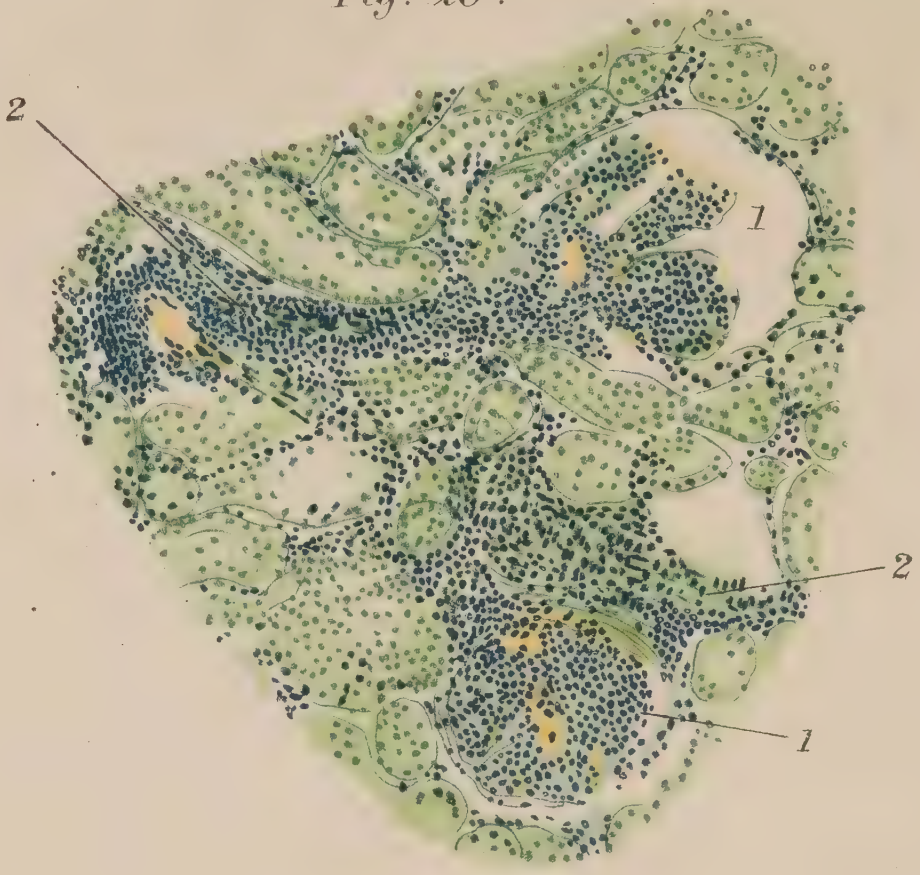
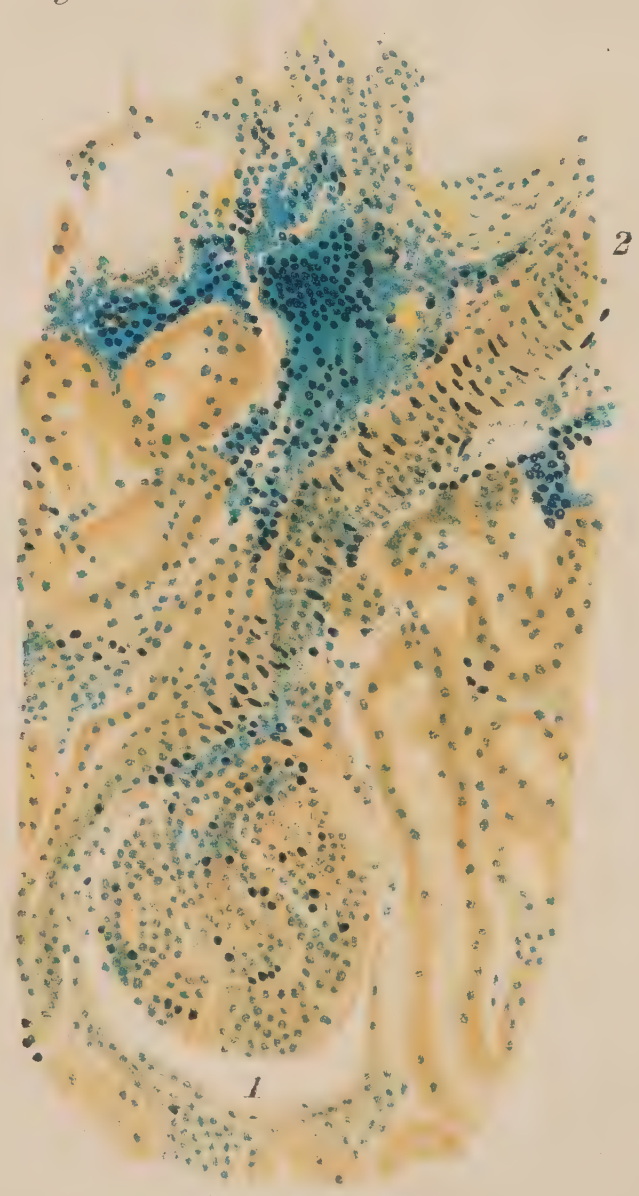


Fig. 21.



HENDON COW DISEASE.

PLATE XVI.

Fig. 20.

From a section through the cortex of the kidney of cow IV. Magnif. power 120.

1. Malpighian corpuscles, the nuclei of the glomerulus greatly increased in numbers: *i.e.*, glomerulo-nephritis.
2. Arterioles, their sheath much infiltrated with round-cells.

Fig. 21.

From a section through the cortex of the kidney of cow III. Magnif. power 200.

1. Malpighian corpuscle, showing very pronounced glomerulo-nephritis.
2. Arteriole, around it masses of round-cells.

HENDON COW DISEASE.

PLATE XVII.

FIG. 22.

From an artificial cultivation in broth of the streptococcus obtained from the ulcer of cow IV., after three days' growth at 36° C.

FIG. 23.

From the same cultivation after 14 days' growth.

Fig. 22.

Fig. 23.

H. Lapidge, del.

Fred^k Dangerfield, Lithographer, London 12307.

Fig. 24.

1

2

3

4

5

M.H.Lapidge, del.

Fredk Darnfield, Lithographer, London. 12305.

HENDON COW DISEASE.

PLATE XVIII.

Fig. 24.

Artificial cultivation of the streptococcus of the cow's ulcer, in test tubes, natural size.

1. On the surface of Agar-Agar mixture.
2. On the surface of nutritive gelatine.
3. On the surface of Agar-Agar mixture.
4. On the surface of nutritive gelatine.
5. In the depth of nutritive gelatine.

on board the Hospital Ships in Long Reach, and convalescents being drafted to the camps at Darenth. And in the practice of that season the limit of 50 cases at one time in hospital was for the most part adhered to; at Homerton only was the limit occasionally exceeded; in none of the other intra-urban hospitals did the number of patients at the date of any fortnightly return much exceed 40. At this time both from Homerton and Hampstead complaint was made that the Metropolitan Asylums Board Hospitals had been spreading small-pox, and in October 1884 an action-at-law was brought against the Managers in regard of the camp at Darenth. About the same time the Asylums Board decided that the maximum number of cases in any intra-urban hospital should (if possible) be limited to 25: orders to this effect came into force in October, and were, with only occasional exceptions, duly observed at each hospital throughout the remainder of the epidemic. In all, from September 1884 to September 1885, some 3,500 acute small-pox cases passed in and out of the intra-urban hospitals, above 4,000 additional acute cases were passed through the ships at Long Reach, and above 7,000 "convalescents" were accommodated in the camps at Darenth. The London small-pox deaths in the period amounted to above 1,900, nearly 1,000 of which occurred in the intra-urban hospitals, 378 in their own homes, above 500 on board the ships, and the remainder (about 50) in the camps at Darenth.

During the period under consideration the circumstances of Fulham Hospital, its internal administration, its communications with the outside world, and its ambulance arrangements, hardly differed from those described in my report of 1884. Such change as was made has been for the most part in the direction of greater stringency; as, for instance, completion of telephonic communication between the Hospital (Ambulance Department) and the Metropolitan Asylums Board offices in Norfolk street, obviating excuse for direct application at the hospital by relations and friends seeking information as to the welfare of patients; better arrangements for transaction of business with tradespeople; complete control of the whole ambulance service of the district, and the like. The most conspicuous alteration at Fulham has been that in October 1884, certain pavilions, which had been previously used for small-pox cases, were brought into use for scarlatina; this being the first occasion when fever and small-pox had been simultaneously received into the Fulham Hospital. While this change was making, from October 3rd to October 15th, all small-pox admissions to the hospital were intermitted. As far as practicable under the circumstances the two sets of pavilions at Fulham were made distinct and separate hospitals; and with the exception of certain cooking arrangements and of medical treatment they have throughout been separately administered with special watchfulness against intercourse of any sort between the two hospitals. The laundry and service of nurses and servants and laundry-women were completely distinct for the two establishments. The northern series of pavilions has constituted the small-pox hospital, the southern series that for scarlet fever. Of course after disuse of the southern pavilions for small-pox, they were thoroughly disinfected and doubtless efficiently so.

Another change that has been made in the use of the hospital deserves notice. It has reference to the stage of their malady at which "convalescents" have been transferred. During the summer of 1884 all transfers from Fulham to the ships or to camp were bonâ fide convalescents, persons, that is, who might, but for possible danger to others, have returned to their homes and to work. In October 1884, strict injunction was given to the medical superintendent to transfer to the

"Ships" each patient as soon as the case would bear removal, and these orders have been observed at Fulham with much fidelity.

As before, small-pox data for Chelsea, Fulham, and Kensington have been obtained from the Metropolitan Asylums Board, the Vestries, the Poor Law authorities, and from medical practitioners. Among the cases recorded as occurring in the three parishes were some few which are known to have had the opportunity of catching their small-pox elsewhere, and a few cases also in regard of which the diagnosis of their malady was open to doubt. Seeing that small-pox was rife in the district at a time when both classes of cases occurred, I have not found it needful to differentiate these few cases.

At the end of September 1884, and in early October, small-pox, which for several consecutive weeks had well-nigh disappeared from the three parishes, began to increase again, especially in Kensington and Fulham. By December it had become generally prevalent and widespread, and throughout the winter months it persisted in the district. About the end of April 1885 there was sudden increase of small-pox, as in May and June of the previous year, in all three parishes; but thenceforward the disease steadily declined, with exception of a particular fortnight of August, until by October it had practically disappeared from the district.

Fulham Hospital was in use during nearly the whole of this period. Though in September 1884 its operations had become well-nigh infinitesimal, the hospital did not become actually emptied of small-pox, and in mid-October of that year, after completion of the arrangements for receiving scarlet fever as well as small-pox into hospital, it commenced again to receive acute cases. Up to the end of November small-pox admissions to Fulham were mainly from other parishes, but thenceforward, with exception of a single fortnight in January 1885, Chelsea, Fulham, and Kensington contributed cases to this hospital in larger numbers than other London districts.* On no one day throughout the second part of the epidemic (352 days) did cases acutely ill in hospital exceed 22, and on 18 occasions only were they so many as 20. Altogether from September 1884 to the beginning of September 1885, when the hospital ceased to receive small-pox, admissions numbered 423, transfers from the hospital were above 300, and the deaths amounted to 115. Tables, maps, and diagrams are appended showing in detail the operations of the hospital and the distribution of small-pox in areas round it during the whole of the epidemic period 1884–85.

The tables are compiled on the plan adopted in my report of 1881. They give the data fortnight by fortnight respecting hospital operations and small-pox incidences. Where a broad and general survey is desired of the facts of hospital operations and associated small-pox, the special area is divided into a central half-mile circle and a half-mile outer zone for the purpose of contrasting small-pox incidences on these several areas and on the remainder of the three parishes; but when it is desired to more especially observe the behaviour of small-pox within the limits of the special area, the latter is divided into a central quarter-mile circle and three successive concentric quarter-mile zones. On the plan of my former report, rates for the special area and its sub-divisions are now taken on the houses existing there in 1884–85; rates for the remainder of the three parishes are taken on the houses therein at the census of 1881, with deduction of the number of houses in the special area. The rates, therefore, for the special area and its sub-

* I may take leave to recall that in these reports the small-pox *admissions* into Fulham Hospital for the three parishes are not taken as any measure of the *incidence* of small-pox upon those parishes.

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divisions are actual rates, whereas rates for the remainder of the three parishes are somewhat unduly high.

In Table A. (page 118), the special area has but two divisions, a central 0–½ mile circle containing the hospital, and a ½–1 mile zone. This table shows that—

(*a.*) In the five months 22nd December 1883 to 24th May 1884, the pre-hospital period of my last report, the incidence of such small-pox as occurred in Chelsea, Fulham, and Kensington, was somewhat greater on parts of those parishes outside the special area than on parts of them within its limits, and twice greater on the ½–1 mile zone of the special area than on 0–½ mile division of it nearest the hospital. At the same time the incidence on the zone was less than that on the "rest of the three parishes."

(*b.*) In the next, the post-hospital period of my last report (25th May to 13th September 1884), these conditions of small-pox prevalence were reversed. During this period the incidence of small-pox on the special area became twice as great as on the rest of the three parishes; at the same time that, within the limits of the special area, the small-pox incidence on the 0–½ mile division of it nearest the hospital became more than double that on its ½–1 mile zone. Meanwhile, the incidence on this zone of the special area became one-and-a-half times as great as the incidence on the "rest of the three parishes."

(*c.*) Towards the close of this post-hospital period, and coincidently with rapid diminution of hospital operations (which were not restricted to cases arising in the three parishes), small-pox ceased to affect the special area, though it lingered in some other parts of the three parishes.

(*d.*) In the period 14th September to 22nd November 1884, while the operations of Fulham Hospital, though growing, continued insignificant, small-pox did not rapidly increase in Chelsea, Fulham, and Kensington. That which occurred there about equally affected the special area and the rest of the three parishes. But of small-pox occurring during this period in the special area, that affecting the 0–½ mile division of it nearest the hospital was about three times as abundant as that in its ½–1 mile zone. On the other hand, that in the zone did not equal the incidence on the "rest of the three parishes."

(*e.*) From the 23rd November 1884 to 6th June 1885, during the whole period of the later major operations of Fulham Hospital, the incidence of small-pox on the special area was more than twice as great as on the rest of the three parishes, and the incidence on the 0–½ mile division of the special area nearest the hospital more than three times as great as on its ½–1 mile zone. The incidence on this outer section of the special area became meanwhile one-and-a-half times as great as that on the "rest of the three parishes."

(*f.*) After June 6th, with rapid decline of hospital operations, the incidence of small-pox on the special area became less than twice that on the rest of the three parishes, and finally, at cessation of hospital operations, hardly exceeded it. Meanwhile, and until the end of August, when the hospital practically ceased to receive small-pox cases, the small-pox incidence on the 0–½ mile division of the special area nearest the hospital was, in comparison with that on its ½–1 mile zone, even greater than before. At the same time the incidence on this zone became smaller than that on the "rest of the three parishes."

To sum up the whole period of hospital operations, 25th May 1884 to 26th September 1885, the incidence of small-pox on houses of the special area was twice as great as that on the rest of the three parishes, and the incidence on the 0–½ mile division of the special area, nearest the hospital, three times that on its ½–1 mile zone. Similarly

the incidence of small-pox on this outer division of the special area was nearly one-third greater than that on the "rest of the three parishes." The facts enumerated for the several periods are exhibited below in tabular fashion, the incidence of small-pox on the "rest of the three parishes" in each period being taken as unity.

And here, at risk of repetition, let me recall that the hospital received small-pox cases from a variety of London parishes besides Chelsea, Fulham, and Kensington; and that, both on the occasion of its fresh use for small-pox (*b*), and of its coming into further use after the ebb of the epidemic (*d*), the earlier admissions were mostly from those other parishes.

Periods of 1884–85.	Acute Cases admitted to Fulham from all parts.	Chelsea, Fulham, and Kensington, relative Small-pox incidence upon Houses of—				
		Three Parishes, outside Special Area.	Special Area.	Three Parishes, outside Special Area.	Special Area.	
					½–1 Mile from Hospital.	0–½ Mile from Hospital.
(*a*.) Dec. 1883 to 24 May 1884	—	1	·7	1	·8	·4
(*b*.) 25 May to 13 Sept. -	162	1	2·1	1	1·5	3·5
(*d*.) 14 Sept. to 22 Nov. -	42	1	1·1	1	·7	2·1
(*e*.) 23 Nov. 1884 to 6 June 1885.	309	1	2·4	1	1·5	4·7
(*f*.) 7 June to 29 Aug. -	65	1	1·9	1	·9	4·4
25 May 1884 to 26 Sept. 1885.	585	1	2·1	1	1·3	4·0

Table B. (page 119), besides further illustrating the facts of table A., deals more precisely with the facts of distribution of small-pox within the limits of the special area. It affords opportunity for comparing fortnight by fortnight the incidence of small-pox in different periods of varying use of the hospital, on each of four several divisions of this area, and for similar periods the incidence on the whole special area, with the incidence on the rest of the three parishes. Making allowance for the circumstance that the central quarter-mile circle containing the hospital comprises only a few hundred houses, and is therefore exceptionally liable to be capriciously affected, the table gives indications during hospital operations of graduated intensity of small-pox incidence from centre to periphery in the special area, and indications also of absence of such graduation when the hospital was not in use for small-pox. Indications of graduation are most abundant in those fortnights of much small-pox, wherein the incidence of the disease on the total special area greatly exceeded that on the rest of the three parishes.

[It deserves notice that in the fortnight ending 6th December 1884, when, in close sequence to sudden and considerable increase of the number of patients on low-diet in hospital, the small-pox rate in the special area became three times greater than in any fortnight since July,—there is exceptional indication of graduation of small pox incidence from centre to periphery. As on other occasions of sudden extension of small-pox over the special area, the fresh invasions of this fortnight were nearly uniformly distributed in all directions around the hospital.—And further, it deserves notice that in this particular fortnight of sudden dissemination of small-pox about the hospital, the newly-established fever hospital was stricken by the disease. Within one week—29th November—5th December, no less than four fever convalescents (not one of whom had been in hospital less than four

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weeks), in two separate pavilions, were attacked by small-pox. At the time when these persons in all probability received their infection, the fever hospital had only been open four or five weeks, and hardly contained 40 patients; the rate of attack, therefore, on these fever wards in a particular week was some 10 per cent. of the patients therein contained. Up to this time, it had not been the practice to re-vaccinate scarlatina convalescents; but when it was seen that they could be attacked by small-pox, itbecame the rule to re-vaccinate each one of them at an early stage of convalescence.—The circumstances are altogether so noteworthy, that I append a map (to be found at the end of this memorandum), showing the local distribution of the small-pox of this fortnight: the scarlatina pavilions are shown as if they were two houses.]

For better examination of the facts as to graduation of small-pox in the several periods of the epidemic, Table B. may be conveniently condensed as follows:—

Total acute Small-pox Cases admitted to M.A.B. Hospitals.	Amount of Use of Fulham Hospital (Cases of Acute Small-pox admitted).	Periods (varying Use of Fulham Hospital).	Chelsea, Fulham, and Kensington Houses invaded, Rate per cent. of Houses.					
			Within One Mile of the Hospital.				In whole of Special Area.	In Rest of the Three Parishes.
			In ¼ Mile Circle.	In ¼–½ Mile Zone.	In ½–¾ Mile Zone.	In ¾–1 Mile Zone.		
1,305	—	Dec. 1883 to 24 May 1884 ("pre-hospital period") 5 months.	—	·026	·070	·020	·040	·060
2,690	160	25 May to 13 Sept. 1884 ("post-hospital period") 4 months.	·660	·761	·404	·250	·454	·212
1,365	44	14 Sept. to 22 Nov. 1884 (minor operations of hospital) 2 months.	·660	·158	·105	·041	·115	·100
6,046	309	23 Nov. 1884 to 6 June 1885 (later major operations of hospital) 6 months.	5·274	1·501	·702	·500	·983	·403
1,150	65	7 June to 29 Aug. 1885 (decline of hospital operations) 3 months.	1·318	·368	·105	·083	·203	·106
12,700	585	25 May 1884 to 26 Sept. 1885, whole period of hospital operations, 1884-85.	7·912	2·844	1·320	·875	1·770	·840

This condensed table, besides exhibiting graduation of small-pox incidence during hospital operations, brings out another fact. It shows that the incidence of small-pox on the total special area has in each period been strikingly proportioned to the total operations of the hospital during the period. This indication of close relation between the amount of hospital operations and the amount of small-pox in the special area is not a new indication; it has been already referred to at page 322 of my 1881 report as being observable when epidemic is compared with epidemic.

And hence arises a question with which the present memorandum may close.—Circumstances of hospital administration have very much changed at Fulham since the Asylums Board recognised the fact of special incidence of small-pox round their hospital. Every practicable means have been taken for limiting the number of communications between the hospital and the outside world, and for rendering any danger to outsiders from such communications infinitesimal; an excellent ambulance service has been provided; and the number of sick in hospital at any one time has been kept down even below the limit which the Hospitals Commission regarded as permissible. Is there evidence to show whether these measures have had influence upon the quantity of small-pox appearing in the houses round the hospital, and if so, what has been the nature of such influence?

In the hope of getting some such evidence, I have put together the facts respecting the areal distribution of small-pox over the three parishes during each of the several periods that have been investigated in these reports; and I present them, in Table C. which follows, for the reader's consideration. In several respects (of more or less importance) the facts of one period are not altogether comparable with the facts of another period.

For example, the number of houses set down as invaded in the three parishes during the periods of my two personal investigations are a nearer approximation to absolute truth than the numbers set down to periods before December 1880 or to the period April 1881 to December 1883, for which I had to be satisfied with data obtainable from all available records; again, the practice of removing convalescents was begun in May 1881, and the effect of this practice, adopted in the middle of an epidemic, should be allowed for in any comparison; and again, of the five epidemic periods into which the years 1877–81 divide, the last must have differed from the first in the number of susceptible people residing in the parishes, and this consideration cannot be exhibited in the table.

But while admitting that there are obstacles to exact comparison between the several periods, there is yet, I think, ground for one broad inference from the table; one that must provisionally be accepted as a reply to the above question. It is that the aggregate of changes introduced into the administration of Fulham Hospital since the epidemic of 1881 have had little or no influence upon the quantity of small-pox distributed, during the recent epidemic, through hospital agency over the houses of the neighbourhood. Under former conditions, each 100 cases received into Fulham Hospital were responsible in some way or other for a certain definable quantity of small-pox in the houses round the hospital: under present conditions, each 100 cases so received have been responsible for at least as much as before.

This being the case, then, if we may credit the improved management of the hospital with the removal of opportunities of personal infection, it follows that some other element in the aggregate of changes has operated to obscure if not to undo whatever good may have been done by the removal of these opportunities. We cannot deal as fatalists with this other element, and give it up as undiscoverable. Only let the proposition, which was submitted in my report of 1881 as helping to explain the facts, be granted; viz., that the potency of small-pox to spread resides mainly in the acute cases* ; and we see at once why a given number of cases, if they be all acute, may do as much harm to a neighbourhood as a larger number of mixed cases, acute, semi-acute, and convalescent, together. And the changes of Fulham administration restricting the number of sick who may be treated in hospital at any one time, have resulted in acute cases being preferred for treatment there. So that I am disposed to re-affirm this proposition, and to find in the preference that has been given to acute cases at the hospital a reason why no profit to the three parishes from improved isolation and ambulance arrangements should be discoverable; a reason why the hospital with 585 cases in 1884–5 was able to injure its neighbourhood to about the same degree as the same hospital with 714 cases (and more flaws in management) in 1878,† or as the same hospital with 679 cases (and the previous flaws in management) in 1878–79.

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* It will be remembered that in the first of these reports a distinction in their ability to spread small-pox between acute and convalescent cases in hospital was seen to be called for.

† In the admittedly rough comparison here presented, I do not mention the different durations of the epidemic periods compared; but these are shown in Table C.

TABLE A.—Showing Fortnight by Fortnight for the Years 1884 and 1885 the OPERATIONS of FULHAM HOSPITAL, and the incidence of SMALL-POX on the nearer and further Divisions of the Special Area, on the whole of that Area, and on the rest of the Three Parishes.

Total Acute Small-pox Cases admitted to M.A.B. Hospitals.	Small-pox Cases from all Sources in Fulham Hospital.					Fortnight ending	Within One Mile of Hospital at Fulham.				Chelsea, Fulham, and Kensington.			
							Houses invaded.		Rate per cent. of Houses.		Houses invaded in		Rate per cent. of Houses.	
	Total Admissions to Fulham.	Severe Cases.	Milder Cases.	Admissions afterwards proving fatal.	Mean Number daily of Low-Diets.		0—½ Mile.	½—1 Mile.	0—½ Mile.	½—1 Mile.	Special Area.	Rest of the Three Parishes.	Special Area.	Rest of the Three Parishes.
30	—	—	—	—	—	5 January 1884	—	—	—	—	—	1	—	·003
34	—	—	—	—	—	19 „ „	—	—	—	—	—	—	—	—
45	—	—	—	—	—	2 February „	—	—	—	—	—	—	—	—
30	—	—	—	—	—	16 „ „	—	—	—	—	—	—	—	—
52	—	—	—	—	—	1 March „	—	—	—	—	—	2	—	—
52	—	—	—	—	—	15 „ „	—	—	—	—	—	—	—	—
153	—	—	—	—	—	29 „ „	—	—	—	—	—	—	—	—
114	—	—	—	—	—	12 April „	1	—	·023	—	1	—	·006	—
142	—	—	—	—	—	26 „ „	—	—	—	—	—	1	—	·003
350	—	—	—	—	—	10 May „	—	3	—	·028	3	9	·020	·027
303	9	7	2	2	4	24 „ „	—	2	—	·019	2	7	·013	·021
573	28	20	8	1	13	7 June „	12	13	·282	·123	25	12	·169	·036
694	43	24	19	4	23	21 „ „	4	7	·094	·066	11	28	·074	·084
537	38	24	14	6	19	5 July „	9	9	·215	·085	18	16	·122	·048
257	23	12	11	3	14	19 „ „	3	5	·070	·047	8	5	·054	·015
185	8	2	6	—	6	2 August „	3	1	·070	·009	4	1	·027	·003
177	6	3	3	—	5	16 „ „	1	—	·023	—	1	6	·006	·018
119	5	3	2	—	3	30 „ „	—	—	—	—	—	1	—	·003
148	2	2	—	—	1	13 September „	—	—	—	—	—	2	—	·006
172	5	2	3	—	3	27 „ „	1	1	·023	·009	2	6	·013	·018
200	1	1	—	—	2	11 October „	2	2	·047	·019	4	7	·027	·021
326	15	9	6	5	4	25 „ „	1	—	·023	—	1	4	·006	·013
297	21	16	5	9	8	8 November „	2	3	·047	·028	5	10	·034	·030
370	27	17	10	5	14	22 „ „	3	2	·070	·019	5	6	·034	·018
485	31	23	8	10	16	6 December „	9	6	·215	·057	15	11	·101	·033
388	22	17	5	10	15	20 „ „	8	8	·188	·076	16	14	·108	·042
339	15	14	1	7	8	3 January 1885	9	4	·215	·038	13	4	·090	·013
448	34	29	5	8	14	17 „ „	7	1	·164	·009	8	8	·054	·024
548	23	20	3	8	13	31 „ „	5	3	·117	·028	8	4	·054	·013
481	21	15	6	8	15	14 February „	5	6	·117	·057	11	5	·074	·015
347	14	12	2	5	7	28 „ „	2	4	·047	·038	6	8	·040	·024
208	4	1	3	1	6	14 March „	6	4	·140	·038	10	5	·067	·015
301	17	14	3	4	7	28 „ „	3	3	·070	·028	6	10	·040	·030
319	28	19	9	7	14	11 April „	5	6	·117	·057	11	5	·074	·015
556	30	22	8	8	18	25 „ „	6	7	·140	·066	13	26	·090	·078
659	30	22	8	8	19	9 May „	2	5	·047	·047	7	17	·047	·051
499	13	4	9	1	13	23 „ „	7	3	·164	·028	10	9	·067	·027
468	15	9	6	2	8	6 June „	7	4	·164	·038	11	7	·074	·021
378	12	4	8	3	8	20 „ „	3	3	·070	·028	6	9	·040	·027
232	13	7	6	1	7	4 July „	4	2	·094	·019	6	7	·040	·021
221	14	10	4	2	7	18 „ „	2	1	·047	·009	3	9	·020	·027
148	6	3	3	1	3	1 August „	4	—	·094	—	4	2	·027	·006
91	5	3	2	1	4	15 „ „	1	1	·023	·009	2	3	·013	·010
80	5	4	1	—	4	29 „ „	6	3	·140	·028	9	5	·061	·015
78	2	1	1	1	1	12 September „	1	—	·023	—	1	3	·006	·010
75	—	—	—	—	—	26 „ „	1	—	·023	—	1	2	·006	·006
37	—	—	—	—	—	10 October „	—	2	—	·019	2	1	·013	·003
25	—	—	—	—	—	24 „ „	—	—	—	—	—	1	—	·003
—	585	395	190	131	—	25 May 1884 to 26 September 1885.	144	117	3·386	1·115	261	277	1·770	·840

Fulham Hospital, 1884–85.

Table B.—Admissions of Acute Small-pox into Fulham Hospital, and Incidence Fortnight by Fortnight of Small-pox on the Several Divisions of the Special Area, on that Area as a whole, and on the rest of Chelsea, Fulham, and Kensington.

Small-pox Cases from all Sources in Fulham Hospital.					Fortnight ending	Within One Mile of Hospital; Houses becoming newly invaded.				In the Three Parishes; Houses becoming newly invaded.		The same in Rates per cent. of Houses.					
						Of which situated:—											
Total Admissions.	Severe Cases.	Mild Cases.	Cases proving fatal.	Mean Number Daily of Low-Diets.		0-¼ Mile.	¼-½ Mile.	½-¾ Mile.	¾-1 Mile.	Special Area, 0-1 Mile.	Rest of the Three Parishes, 1-3¼ Miles.	0-¼ Mile Circle.	¼-½ Mile Zone.	½-¾ Mile Zone.	¾-1 Mile Zone.	In Special Area.	In rest of Three Parishes.
—	—	—	—	—	Dec. 1883 to 26 April 1884	—	1	—	—	1	4	—	·02	—	—	·00	·01
—	—	—	—	—	14 May 1884	—	—	3	—	3	9	—	—	·05	—	·02	·02
9	7	2	2	4	15 to 24 May "	—	—	1	1	2	7	—	—	·01	·02	·01	·02
28	20	8	1	13	7 June "	2	10	8	5	25	12	·44	·26	·14	·10	·17	·03
43	24	19	4	23	21 " "	—	4	4	3	11	28	—	·10	·07	·06	·07	·08
38	24	14	6	19	5 July "	—	9	7	2	18	16	—	·23	·12	·04	·12	·04
23	12	11	3	14	19 " "	—	3	4	1	8	5	—	·07	·07	·02	·05	·01
8	2	6	—	6	2 Aug. "	1	2	—	1	4	1	·22	·05	—	·02	·02	·00
6	3	3	—	5	16 " "	—	1	—	—	1	6	—	·02	—	—	·00	·01
5	3	2	—	3	30 " "	—	—	—	—	—	1	—	—	—	—	—	·00
2	2	—	—	1	13 Sept. "	—	—	—	—	—	2	—	—	—	—	—	·00
5	2	3	—	3	27 " "	—	1	1	—	2	6	—	·02	·01	—	·01	·01
1	1	—	—	2	11 Oct. "	1	1	2	—	4	7	·22	·02	·03	—	·02	02
15	9	6	5	4	25 " "	1	—	—	—	1	4	·22	—	—	—	·00	·01
21	16	5	9	8	8 Nov. "	—	2	2	1	5	10	—	·05	·03	·02	·03	·03
27	17	10	5	14	22 " "	1	2	1	1	5	6	·22	·05	·01	·02	·03	·01
31	23	8	10	16	6 Dec. "	2	7	3	3	15	11	·44	·18	·05	·06	·10	·03
22	17	5	10	15	20 " "	1	7	6	2	16	14	·22	·18	·10	·04	·10	·04
15	14	1	7	8	3 Jan. 1885	3	6	2	2	13	4	·65	·15	·03	·04	·09	·01
34	29	5	8	14	17 " "	3	4	—	1	8	8	·65	·10	—	·02	·05	·02
23	20	3	8	13	31 " "	4	1	2	1	8	4	·88	·02	·03	·02	·05	·01
21	15	6	8	15	14 Feb. "	—	5	4	2	11	5	—	·13	·07	·04	·07	·01
14	12	2	5	7	28 " "	—	2	3	1	6	8	—	·05	·05	·02	·04	·02
4	1	3	1	6	14 March "	2	4	3	1	10	5	·44	·10	·05	·02	·06	·01
17	14	3	4	7	28 " "	2	1	2	1	6	10	·44	·02	·03	·02	·04	·03
28	19	9	7	14	11 April "	2	3	5	1	11	5	·44	·07	·08	·02	·07	·01
30	22	8	8	18	25 " "	—	6	4	3	13	26	—	·15	·07	·06	·09	·07
30	22	8	8	19	9 May "	1	1	2	3	7	17	·22	·02	·03	·06	·04	·05
13	4	9	1	13	23 " "	3	4	1	2	10	9	·65	·10	·01	·04	·06	·02
15	9	6	2	8	6 June "	1	6	3	1	11	7	·22	·15	·05	·02	·07	·02
12	4	8	3	8	20 " "	1	2	2	1	6	9	·22	·05	·03	·02	·04	·02
13	7	6	1	7	4 July "	2	2	2	—	6	7	·44	·05	·03	—	·04	·02
14	10	4	2	7	18 " "	—	2	—	1	3	9	—	·05	—	·02	·02	·02
6	3	3	1	3	1 Aug. "	1	3	—	—	4	2	·22	·07	—	—	·02	·00
5	3	2	1	4	15 " "	—	1	1	—	2	3	—	·02	·01	—	·01	·01
5	4	1	—	4	29 " "	2	4	1	2	9	5	·44	·10	·01	·04	·05	·01
2	1	1	1	1	12 Sept. "	—	1	—	—		3	—	·02	—	—	·00	·01
—	—	—	—	—	26 " "	—	1	—	—	1	2	—	·02	—	—	·00	·00
—	—	—	—	—	10 Oct. "	—	—	1	1	2	1	—	—	·01	·02	·01	·00
—	—	—	—	—	24 " "	—	—	—	—	—	1	—	—	—	—	·00	·00
585	395	190	131	—	25 May 1884 to 26 Sept. 1885	36	108	75	42	261	277	7·91	2·84	1·32	·87	1·77	·84

TABLE C.—SHOWING PERIODICAL DISTRIBUTION of SMALL-POX on Areas in CHELSEA, FULHAM, and KENSINGTON, around FULHAM HOSPITAL.

Period.	Comprising.	Acute Small-pox Cases admitted to Fulham Hospital in Period.	Number of Houses invaded by Small-pox during Period; the Houses being situated at the several Distances from the Hospital as shown below.						Rate per cent. of Houses.					
			Within a quarter Mile Circle.	In ¼–½ Mile Zone.	In ½–¾ Mile Zone.	In ¾–1 Mile Zone.	Within One Mile, being the Special Area.	In Remainder of the Three Parishes.	0–¼ Mile Circle.	¼–½ Mile Zone.	½–¾ Mile Zone.	¾–1 Mile Zone.	Special Area.	Remainder of the Three Parishes.
March 1876 to March 1877	*12 months*	—	*1*	*2*	*8*	*7*	*18*	*126*	*·23*	*·05*	*·18*	*·19*	*·15*	*·54*
March 1877 to end of 1877	9 „	327	15	48	54	13	130	202	3·47	1·37	1·27	·36	1·10	·86
January 1878 to September 1878	9 „	714	20	89	78	24	211	157	4·62	2·55	1·84	·67	1·80	·67
September 1878 to September 1879	12 „	679	19	92	63	23	197	110	4·40	2·63	1·49	·64	1·68	·47
September 1879 to December 1880	15 „	292	8	37	13	10	68	24	1·85	1·06	·30	·28	·58	·10
December 1880 to December 1881	13 „	1,778	32	132	116	52	332	264	7·39	3·77	2·74	1·45	2·83	·80*
December 1881 to May 1884	*28* „	—	—	*3*	*8*	*1*	*12*	*47*	—	*·07*	*·16*	*·02*	*·10*	*·13*
May 1884 to September 1885	15 „	585	36	108	75	42	261	277	7·91	2·84	1·32	·87	1·77	·84
Whole period of hospital operations	6 years	4,375	130	506	400	165	1,201	1,041	30·1	14·5	9·5	4·6	10·2	3·1

NOTE.—The figures in italics are for periods when Fulham Hospital was not in use for small-pox. None of these figures, therefore, are included in the bottom line of the table. The rates of that line are taken on the houses of the 1880–81 survey.

* Correction has been here made for peripheral growth of the parishes as learned from the census of 1881 Before that census was available, the more distant houses were taken on the enumeration of 1871, with the result of giving too high a rate for parts beyond the special area.

Map A. (reproduced from the 1884 Report) shows the distribution of small-pox in Chelsea, Fulham, and Kensington in the period 25th May to 13th September 1884.

Map B. gives similar facts for the period 14th September 1884 to 26th September 1885.

[*Map C.* gives the facts of distribution of small-pox in the special area, and in the rest of the three parishes, for the fortnight ending 6th December 1884. (See paragraph in square brackets on pages 115–6.)]

Diagrams A. and B. show for the sub-period, 14th September 1884 to 26th September 1885, and for the whole epidemic period, 25th May 1884 to 26th September 1885, the indifference of direction of distribution of small-pox in the special area, as denoted by the graduation of small-pox incidence, being closely similar in each of four separate quadrants of that area. [A similar diagram has been given, page 71 of 1884 Report, for the period 25th May to 13th September 1884.]

Diagrams C. and D. give similar facts for each of the same two periods, a different quadrature of the special area being taken.

Table C. is added, showing for each of six periods since establishment of Fulham Hospital in 1877, the amounts of acute small-pox received into hospital, and the extent to which, in each period, houses in the several sections of the special area, houses in the whole of that area, and houses in the rest of the three parishes, became invaded by small-pox.

MAP A.

25TH MAY 1884, TO 13TH SEPT. 1884.

DANGERFIELD LITH. 22 BEDFORD ST COVENT GARDEN 12434 (8-86)

MAP B.

14TH SEPT. 1884, TO 26TH SEPT. 1885.

---- Parish Boundaries.
—— Carriage Roads.
------ Railways.
▒▒▒ Inhabited Areas
• { Houses within Chelsea Fulham & Kensington invaded by Smallpox.

Portion of West London, showing whole of parishes of **Chelsea** *and* **Kensington**, *and whole of* **Fulham** *District, with adjacent parishes and districts or parts of them.*

Scale; 2 Inches to a Mile.

0 ½

DANGERFIELD LITH. 22 BEDFORD ST COVENT GARDEN 12434/8·86

MAP C.

FORTNIGHT ENDING 6TH DECEMBER 1884.

Scale; 2 Inches to a Mile.

0 1/2 1

DANGERFIELD LITH 22 BEDFORD ST COVENT GARDEN 12435(8·86)

SPECIAL AREA AROUND FULHAM HOSPITAL, SMALL-POX INCIDENCE ON HOUSES.

Figures denote the number, in every hundred houses, invaded.

A

Period 14th Sept 1884 to 26th Sept. 1885.

B

Period 25th May 1884 to 26th Sept. 1885.

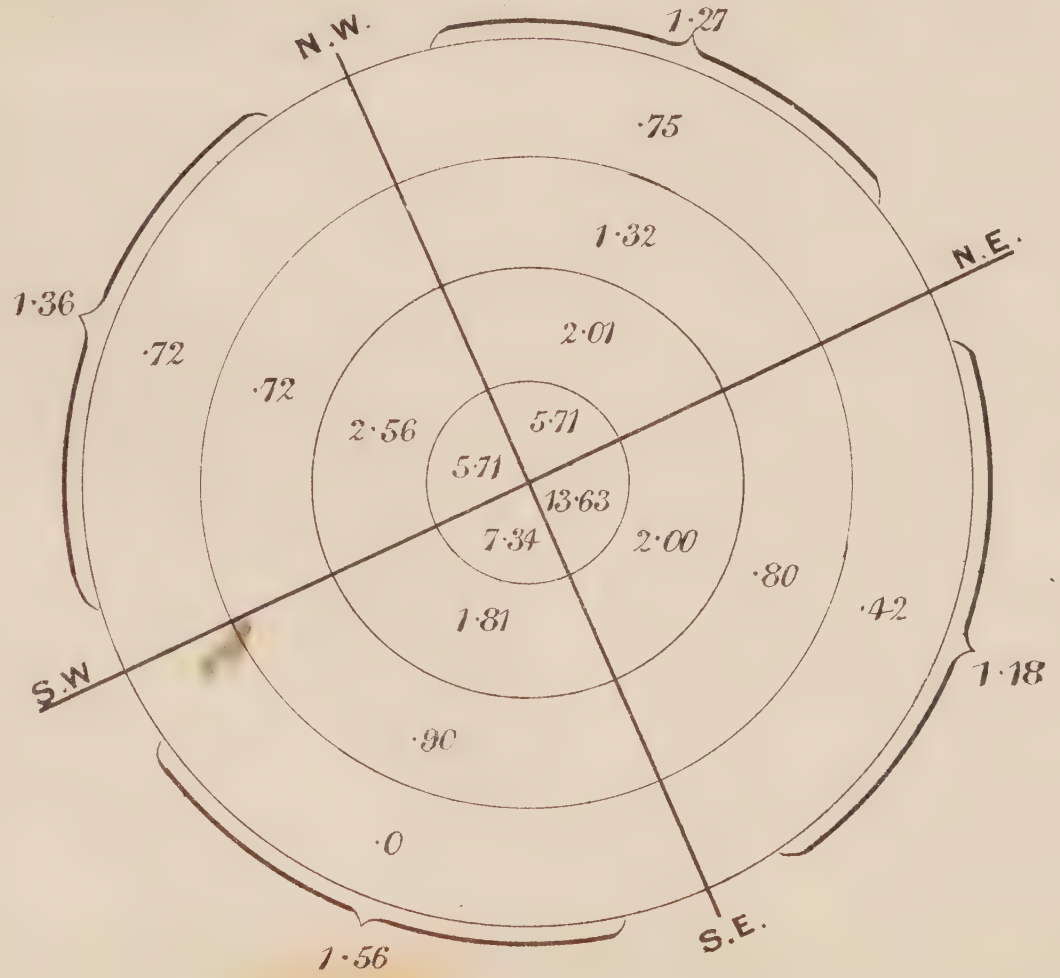
DANGERFIELD, LITH. 22, BEDFORD ST COVENT GARDEN. 11371. 1/86.

SPECIAL AREA AROUND FULHAM HOSPITAL, SMALL-POX INCIDENCE ON HOUSES.

Figures denote the number, in every hundred houses, invaded.

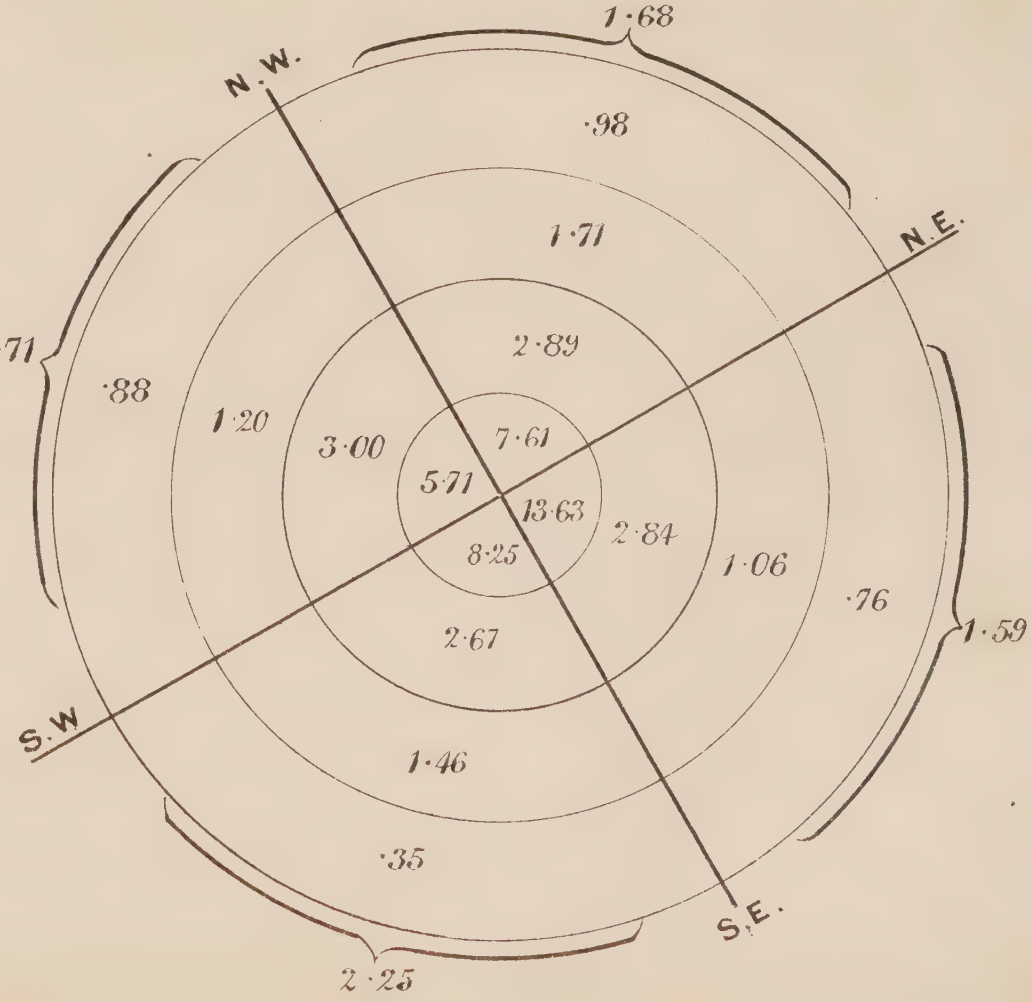
C

Period 14th Sept 1884 to 26th Sept, 1885.



D

Period 25th May 1884 to 26th Sept 1885



DANGERFIELD, LITH. 22, BEDFORD ST COVENT GARDEN. 1/371. 1/86

APPENDIX B.

No. 1.

On the Etiology of Foot-and-Mouth Disease; by E. Klein, M.D., F.R.S.

Statements of previous observers.

The nature and character of the contagion of this disease have been so far altogether unknown. There exist indeed some fragmentary assertions as to the occurrence in the vesicles and ulcers of micrococci (Bender), of saccharomyces mycoderma and other fungi (Spinola); but in the present state of mycological research, mere assertions, unsupported as those are by any satisfactory evidence, and which have not moreover been gained by exact methods, cannot be accepted as of any great value as help toward identification of a material cause of the disease. Cnyrim (Jahrb. d. Rinderh. xxviii., p. 55), describes an epidemic of foot-and-mouth disease in children and adults in Frankfort between October 18th and November 7th, 1884, referred to the consumption of milk of cows similarly affected, and he states that Dr. A. Libbretz examined the contents of the vesicles on the udders of the cows suffering from foot-and-mouth disease, and that from the fluid of such vesicles he cultivated in artificial media four different kinds of microbes. Of these Cnyrim regards a large micrococcus forming white colonies on nutritive gelatine and slowly liquefying its substance, as possibly the contagion, and this supposition is he thinks supported by the fact that the same organism has been cultivated from the milk of cows suffering from the disease.

Recent investigations:

I propose to describe the results of a recent investigation into the nature of the contagion of foot-and-mouth disease which show conclusively that it is identifiable with a definite kind of micrococcus. At the same time I give a description of the anatomical characters of the vesicles and ulcerations occurring in sheep affected by this disease.

At Ampthill:

At Ampthill (Bedfordshire) there occurred in the early summer of 1885 an outbreak of foot-and-mouth disease amongst cattle and sheep owned by a Mr. Swaffield and grazing in Ampthill Park. By the kindness of Mr. Cope, of the Agricultural Department of the Privy Council, to whom I am greatly indebted for aid in this and in subsequent inquiries, I obtained an opportunity of investigating the outbreak. Of the cattle infected, all the animals were too far advanced in their illness for likelihood of any satisfactory result from investigation; but among the sheep there were some that appeared to be in the earlier stages of the malady, and one which I selected for investigation had a distinct unbroken vesicle about the size of a sixpence on the side of the right hind foot just where the horny hoof is in contact with the skin; a spot not unusual for the development of a vesicle in this malady. The vesicle was still covered with thick epidermis, but the fluidity of its contents could be easily felt. In addition the skin in the cleft between the hoofs of both hind feet was beginning to ulcerate. In the mouth, there were on the mucous membrane of the gums two small commencing ulcers, each not more than one-eighth of an inch in diameter. The animal was killed by bleeding, and all the parts, including the above-mentioned vesicles and ulcerations, were carefully cut out and preserved in hardening fluids for anatomical examination. But before death of the animal the unbroken vesicle, above mentioned as existing at the side of its right hind foot, was opened by a small incision (made with a scalpel previously sterilised in the flame of a spirit lamp), and into it the

the disease in sheep.

pointed end of a freshly drawn out capillary glass pipette was plunged and clear lymph collected. With this lymph a number of test tubes, some containing nutritive gelatine, others nutritive Agar-Agar meat extract peptone, were inoculated for artificial cultivation of any germs that might be present in the lymph. The rest of the lymph not used for inoculation, was employed for making cover glass specimens, *i.e.*, it was spread out in thin films on cover glasses, dried carefully over the flame of a spirit lamp and stained with the usual aniline dyes. Some specimens were stained with Spiller's purple, others with Weigert's gentian violet.

Lymph of the vesicles :

Microscopic examination of the lymph thus prepared revealed facts as follow :—

In a homogeneous fluid medium there are distributed three kinds of nucleated corpuscles: (*a*) cells of various sizes, spherical or oval or irregular in outline, and containing several irregularly-shaped nuclei surrounded by a larger or smaller zone of clear protoplasm. These correspond to ordinary plurinucleated pus-cells, or exudation cells, or leucocytes ; (*b*) larger oval or spherical cells with a single nucleus ; and (*c*) cells which are clearly epithelial, as is shown by their containing pigment ; they are rounded and contain an oval clear nucleus. Then, in addition, there are present in the fluid various corpuscular elements which by their various transitional forms can be easily identified as larger or smaller portions of the above referred-to cellular elements in the process of disintegration. Especially are escaped nuclei of the above cells met with very numerously, entire, or vacuolated and in the process of breaking up. Also there occur droplets of hæmoglobin of various sizes, from that of a granule to that of the size of a red blood corpuscle. They are no doubt parts of disintegrated red corpuscles.

Finally, in the lymph of the vesicle, we meet with a few organisms belonging to one and the same species of micrococcus, occurring as single spherical micrococci, or as a dumb-bells (the latter form is oftener met than the former), or more rarely as streptococcus chains made up of four to six elements of the micrococcus.

their anatomical structure. (*See Plates I.-IV.*)

As regards the minute anatomy of the vesicle, sections made through the entire vesicle (that removed from the side of the foot) and the skin adjacent to it, duly stained and mounted, showed the following characters :—In the central region the superficial corium and the papillæ are densely and almost uniformly infiltrated with round cells, and similar cells surround all vessels, large and small, throughout the entire thickness of the corium. In the peripheral portions of the vesicle the infiltration becomes less and less, and it is not found at all in the skin bordering the vesicle. In some of the enlarged (thickened) papillæ, besides the round cells, isolated red blood corpuscles are met with. Here, too, I have seen blood vessels much enlarged and even ruptured with extrusion *en masse* of blood they had contained.

The superficial layers of the epidermis, *i.e.*, the stratum corneum, which also forms the substance of the horny hoof, pass over the vesicle, the latter being made up of a number of larger and smaller cavities extending in a vertical direction through the whole thickness of the stratum Malpighii. These cavities are separated from one another by longer and shorter thin trabeculæ of epithelial cells. In the centre of the vesicle the cavities are largest and longest in a vertical direction, reaching from the superficial corium with which they directly communicate up to the stratum corneum ; in peripheral portions of the vesicle these cavities become fewer and smaller and are separated by thicker trabeculæ of epithelial cells, until finally at the margin of the vesicle they disappear altogether. A careful examination of the marginal portion of the vesicle leaves no doubt that the above cavities are formed

Figure 1.

chiefly from the papillæ themselves. An enlargement of these takes place by the exudation of fluid and leucocytes, and as the fluid exudation into them increases, the papillæ expand and are transformed into oblong cavities. At first the cavities thus formed are still separated by the epithelium, but their contents, *i.e.*, leucocytes and fluid, burrow in many places into the surrounding epithelium, and this process continuing laterally, the epithelial cells become loosened and detached, singly or in groups, and then mingle with the contents of the cavity; so that finally only thin trabeculæ composed of epithelial cells are left separating neighbouring cavities. The process of burrowing into the epithelium adjoining the papillæ by the fluid and round cells of the cavities therein leads to the formation in many places in the epithelium of small cavities, which gradually enlarge and become confluent with one another and which communicate also with cavities of the papillæ. This is particularly pronounced in the marginal portion of the vesicle. The destruction of the epithelium over the papillæ (which normally extend as thin streaks of corium tissue through the whole thickness of the epithelium—stratum Malpighii—up to the stratum lucidum), and its further reduction to thin septa between the enlarged papillæ, does not, at any rate in the marginal portions, extend through the entire length of the papillæ, but, except in the very centre of the vesicle, occurs at various points in the length of the various papillæ. Hence a series of terraces of small cavities are formed, some belonging to the upper, some to the middle, and some to the deeper layer of the epithelium; in the very centre of the vesicle the cavities are longest, some extending throughout the whole thickness of the epithelium and becoming directly continuous with the superficial corium. The smaller cavities are filled with round cells, and amongst them loosened and rounded epithelial cells, some of them still filled with the original pigment granules. The larger cavities contain an albumenoid fluid, and in it are masses of round cells, loosened epithelial cells, many of them without a nucleus and in the process of breaking up. In specimens that have been hardened, the fluid contents of the cavities are represented by a granular substance and something like fibrin deposit. The larger the cavities the greater the amount of fluid as compared with the number of cells present. In the centre of the vesicle the cavities, owing to thinning of the stratum lucidum, gradually break through it, and then their contents, cells and fluid, spread over the free surface of the epithelium; this enlargement of the cavities proceeding beyond the centre of the vesicle, the opening enlarges, and thus finally an ulcer is formed. The cells contained in the vesicle itself are either round cells or exudation cells such as are contained in the papillæ, *i.e.*, protoplasmic corpuscles, spherical, oval, or irregular in outline, and containing several small nuclei or one large clear nucleus; or they are single isolated epithelial cells, or groups of such cells, some containing pigment granules similar to those normally found in some of the epithelial cells of the stratum Malpighii in these localities. There occur also apparently free nuclei, and nuclei in the process of breaking up into small irregular particles. Finally droplets of hæmoglobin and more or less perfect red-blood discs are found in the vesicles.

Figure 4. *Figure* 1. *Figure* 1. *Figure* 4. *Figure* 2.

It appears, then, that as regards the vesicle, the whole disease process is an acute inflammation of the corium and papillæ, leading to the exudation of round cells and fluid, whereby the papillæ become greatly enlarged and the epithelium surrounding them eventually involved. Then finally, the disease continuing to progress, the cavities open. Where the stratum lucidum is very thick and resistant, as on the hoof, distinct cavities are formed, and these become filled with fluid and

Figures 1 *and* 4.

exudation cells; in other localities, where the stratum lucidum (and the epithelium as a whole) is thin, the contents of the enlarged papillæ soon escape through it, and are poured out on to the free surface, with the result that an ulcer is established.

Figures 2 and 3. Ulcerations.

Figures 2 and 3. In the ulceration in the cleft between the hoofs, and in the ulceration of the mouth, the anatomical features are very similar; but there is not formation of so large cavities. There is, however, in these situations as in the vesicle, uniform infiltration with abundant appearance of round cells in the superficial corium and papillæ, these latter becoming hereby much thickened. The contents of the papillæ extend into and beyond the stratum lucidum, and this, as well as the stratum Malpighii, becomes involved, and, in the end gradually destroyed, with the result that a direct communication is established between the surface and the corium, so that the contents of the papillæ extend over the free surface of the ulcer. The deeper parts of the corium show also infiltration with round cells around all vessels and glands; this infiltration is greatest in the centre of the ulcer and gradually diminishes towards the periphery. But by and by in the periphery also, infiltration of the papillæ gradually increases, and in the end, the stratum lucidum here is broken through.

Organisms found in the Tissue of the Vesicle of the Foot of the Sheep.

Search for organisms in diseased tissues:

Examination of sections made through the unbroken vesicle (that removed from the side of the hoof), after hardening and staining by methods best adapted for demonstrating the existence of bacteria in tissues, yielded results far from satisfactory.

In searching for bacteria in the contents of the cavities and papillæ it is necessary to be able to set aside certain elements which, from their size and other characters, might be mistaken for organisms.

of the vesicles;

(1.) There is first the pigment of the epithelium. As already mentioned, numerous epithelial cells, naturally containing pigment, become detached and mixed up with the contents of the cavities; and these detached epithelial cells gradually disintegrating, set free granules of a light or dark-brownish colour amongst the contents of the cavities. In addition must be mentioned as present in the fluid of the cavities other pigment granules which were originally contained in branched pigment cells situated normally between the layer of epithelial cells immediately surrounding the papillæ and which were present also normally in the tissue of the papillæ. In specimens stained with blue, violet, red, or brown aniline dyes (gentian violet, fuchsin, vesuvin) the colour of these pigment granules is not so very strikingly different from that of stained organisms as to suffice at once to distinguish them; and since some of them appear as double granules, or dumb-bells, their being mistaken for dumb-bell micrococci is not an improbable occurrence. The particles or granules normally present in the epithelial cells of the superficial layer of the stratum Malpighii (the stratum granulosum) which stain deeply with aniline dyes, cannot, however, owing to the locality of their occurrence, and particularly to their great variety in size and shape, be easily mistaken for micro-organisms.

(2.) In the larger cavities a good many globules of various sizes, from that of a minute granule to that of the nucleus of a leucocyte, are to be met with which take the aniline dye. When these are small they could be mistaken for micrococci. These globules, however, lose the dye if, after staining, the sections containing them are well washed in alcohol and clove-oil. In specimens decolourised after Gram's method, *i.e.*, by iodide, dissolved in iodide of potassium, the above granules invariably become decolourised. These globules, as has been already

mentioned, are derived from two sources, viz., from the nuclei of disintegrating leucocytes and from red blood corpuscles.

(3.) Bits of fibrin threads also occur, which when granular might be mistaken for chains of micrococci, and when smooth for bacilli. But this mistake will scarcely be made in stained specimens, as these fibrin threads do not retain the dye after the sections have been, as they usually are before mounting, washed in alcohol and clove oil.

bacilli; But in some of the sections through the above vesicle after staining well with fuchsin followed by decolourising after Gram's method, and further staining with vesuvin, I have met with bacilli in one or another of the superficial cavities of the vesicle. Some of these bacilli, which were slender, of about the same length as tubercle bacilli, and which had retained the colour of the fuchsin, showed in a pale sheath their protoplasm as granules, stained deep pink and collected, one at each end, with sometimes a third granule in the middle; but most of the bacilli are conspicuous by their fuchsin colour. These bacilli very much resemble the syphilis bacillus of Lustgarten, which has been, however, recently met with by Bienstock, Gottstein, and others (Fontschritte Medizin, 1886) also in the smegma and amongst the epithelium of the sebaceous follicles of the normal skin. In another section I have met with the same kind of bacilli in a distended lymph vessel of the superficial part of the corium.

[As will be mentioned later on, the above bacilli, when cultivated outside the animal body and subsequently injected into animals, had not the faculty of communicating foot-and-mouth disease.]

micrococci Besides these bacilli, minute micrococci are found, but sparingly, in the cavities, in the form of single micrccocci and as dumb-bells. In the superficial cavities they are as a rule most numerous. They are fairly well seen in sections stained with fuchsin and afterwards decolourised after Gram's method; but they are better seen in sections stained thoroughly with Weigert's gentian violet and afterwards treated with alcohol and clove oil so as to wash out a good deal of the dye. I have seen them also in specimens stained deeply in methylblue, prepared with aniline oil after Weigert's method. In specimens thus prepared they come out well in the superficial cavities, particularly in the peripheral portions of the vesicle, where they are to be met with as small clusters escaping from the tissue of the papillæ into the surrounding epithelium and finding their way upwards towards and into the stratum lucidum. The most notable specimens are, however, those stained successfully in Weigert's gentian violet, for in some of the sections of cavities thus prepared (provided sufficient of the dye has been removed), there are found beautiful chains of micrococci streptothrix. I have seen chains of these micrococci twisted and convoluted and each containing over 30 of the micro-organisms. These chains are very distinct and they are of essential importance, since one might mistake a single stained granule for a micrococcus, or a double granule for a diplococcus; but that these chains are streptococcus there can be no mistake at all. This streptococcus, although far from being numerous, even in some very successfully stained specimens, was found embedded amongst the cells in the fluid contents of some of the larger cavities. It is a difficult matter to hit off the exact point at which to cease withdrawing the dye from a given specimen; for too much decolouration is apt to withdraw the dye from the chains also. Although I possess many sections through the vesicle in the cavities of which beautiful chains of streptococcus are present, I must confess that I do not consider their demonstration in point of numbers as satisfactory as I could wish, the reason, I presume, being, that I have not yet hit on the very best method for staining them, although large

or streptococcus.

numbers of preparations have been stained in all the known modifications and combinations of the methods usually employed for demonstrating bacteria within the tissues.

In some sections stained with fuchsin and decolourised after Gram's method and stained afterwards with vesuvin, I have seen the same micrococci, singly, in dumb-bells, and in small clusters, amongst the blood corpuscles filling some of the larger blood vessels of the corium itself, and from the lumen they could be traced into the wall of the vessel and thence among the round cells infiltrating the tissue surrounding the vessel.

On the whole then there can be no doubt that minute micrococci (as to their size, see details later on) occur in the contents of the superficial as well as of the deeper cavities, and in and around the blood vessels of the corium. From the superficial cavities they can be traced into the surrounding epithelium. These micrococci occur singly, as dumb-bells, as small groups, and what is particularly interesting as chains, or streptococcus. Their number on the whole is small in the tissue of the unbroken vesicle such as we have been hitherto considering. More satisfactory in this respect is the examination of the sections made of the tissue of the cleft of the hoofs and of the tissue of the ulcerations of the mucous membrane of the mouth. Of the sections of the former, a single one stained with fuchsin decolourised after Gram's method and then stained again with methylblue, showed in the sweat gland tubes a few of the same bacilli mentioned previously stained pink. But all sections stained with Weigert's gentian violet, and particularly those stained with methylblue prepared after Weigert's method, exhibited the small micrococci, singly and in dumb-bells, in the infiltrated tissue surrounding the blood vessels of the corium, and in the papillæ; and extending along with the swollen contents of the papillæ into the epithelium. Especially in the superficial parts of the infiltrated papillæ were found a number of micrococci in smaller and larger groups, and amongst them many curved chains. The masses of micrococci amongst the exudation cells that had broken through the stratum lucidum and were extending over the free surface of the ulcer were very great. In the ulcers of the mouth the chains of micrococci in specimens stained with Weigert's methylblue were very numerous and distinct, in some places forming clusters. This was particularly the case in the exudation extending from the swollen papillæ through the broken stratum lucidum on to the free surface of the mucous membrane.

in tissue of the ulcers also.

Summary as to micro-organisms.

To sum up then:—there were found in the diseased tissues two kinds of organisms; (*a*) bacilli of the size of tubercle bacilli. These stained in fuchsin after Gram's method, resemble the bacilli described by Gottstein and others as occurring normally in sebum and between the epithelial cells of sebaceous glands. From their distribution and morphological characters, I do not doubt that the two kinds of bacilli are identical. The number of them found was limited and they occurred in very few sections only; they did not occur in the ulcers of the mucous membrane. And (*b*), small micrococci occurring singly, as dumb-bells and particularly as longer or shorter chains or streptococcus. Their number was not on the whole very large, but they were present in all the sections; they occur in the cavities of the vesicle, and amongst the superficial parts as well as amongst the cell infiltrations of the deeper parts of the corium. They are found less abundantly in the vesicle stage, more abundantly in the formed ulcers, most abundantly in the superficial exudation of the ulcer of the mouth.

Artificial Cultivation of Organisms found in the Vesicles.

Bizzozero first pointed out the occurrence of micro-organisms in the epidermis of the normal skin, and Bordoin-Uffreduzzi isolated them (Fortschritte d. Med. N. 5, 1886, p. 151), and found that they presented in artificial media definite characters by which they can be distinguished from one another. He thus ascertained the existence in the skin of several species of micrococci. Of these, one from its morphological characters and from its behaviour on nutritive gelatine, appears to me identical with the large micrococcus isolated by Liebbretz and stated by Cnyrim to be in all probability the contagion of foot and mouth disease. Another species of micrococcus of the skin is always developed in connexion with hairs and with hairs only. This is of special importance only in so far as it goes to invalidate the assertions of Sehlen and others as to an intimate relation existing between micrococci similar to this and certain diseases of the hairs.

Besides these micrococci, Bordoin-Uffreduzzi isolated also a sarcina, bacillus and a species of bacterium, bacterium graveolens. He obtained it from epidermic scales of the normal skin between the toes. This bacterium growing on gelatine, blood serum, and potatoes, developed a fœtid odour similar to that emanating in certain cases from the feet. Evidently this is the same bacterium as that which Dr. Thin and Professor Rosenbach have noted as causing the fœtid odour in profuse sweating.

Culture of these organisms.

Proceeding now to record my own observations: With lymph from the vesicle at the side of the foot of the sheep, obtained under precautions already noted, I inoculated a series of tubes containing sterile nutritive gelatine or sterile Agar-Agar meat extract peptone. The inoculation was performed in each instance by drawing upwards the sterile cotton wool plug in the orifice of the test tube, and pushing through the remainder or lower portion of the plug the pointed end of the charged capillary pipette, and inserting the lymph at a given point on the surface of the sterile nutritive medium. Out of a dozen gelatine tubes thus inoculated and kept in the incubator at 20° C., two showed after several days a growth at the point of inoculation. The Agar-Agar tubes inoculated were also 12 in number; these were kept in the incubator at 36° C., and after 48 hours three showed a growth at the point of inoculation.

In one gelatine and one Agar-Agar tube of the above series, the growth on microscopic examination proved a motile bacillus; this, as it increased in numbers, liquefied the gelatine and formed a pellicle on the surface. On Agar-Agar exposed to 36° C. it grew very rapidly, and formed a thick whitish layer extending very rapidly over the surface of the medium. In size and other characters it was comparable to a small species of bacillus subtilis.

Of streptococcus.

In the second gelatine tube, and in the two other Agar-Agar tubes, the growth which occurred had altogether different characters; characters very peculiar, and in no respect resembling the character of the growths observed by Bordoin-Uffreduzzi as already mentioned. The peculiarity noticed about this growth was its extremely slow progress. In the gelatine tube, after one week, the growth was extremely small, in fact limited literally to the point of inoculation. In the two Agar-Agar tubes, even after 16 days' exposure to 36° C., the growth consisted of small collections of translucent round flat droplets or granules, placed closely side by side. From one of these Agar-Agar tubes subcultures were established in a series of tubes containing gelatine, Agar-Agar, serum, sterile milk, sterile broth, meat extract solution with peptone 1 p.c.; and sterile broth with peptone (1 p.c.). The characters of the growth in these different nutritive media were thus studied, and micro-

scopic specimens were made of the growths carried out under these different conditions. All the tubes, except those containing gelatine (which were kept at a temperature between 19° and 21° C.), were kept at 35°–37° C.

its mode of growth in various media;

The characters of the growths are the following [Plates VII. and VIII.] :—

(*a.*) *In the ordinary Fluid Media* (broth, broth peptone, meat extract peptone), there appears as soon as 24 hours after incubation at 35° C. a very slight and uniform turbidity which increases during the next few days; at the end of a week the growth has reached its maximum, but the turbidity is not at any time very great. Before this point is reached some growth begins to settle down as a whitish powdery moss; and after 10 to 12 days or so the fluid has become quite clear, the whole growth having settled down as a moss, which is comparatively very small in bulk.

The growth succeeds in neutral fluid, but flourishes better and grows more copiously if the medium be faintly alkaline. As the growth advances the medium assumes a slightly acid reaction.

(*b.*) *In Sterilized Milk*, the growth proceeds slowly; at no time, not even after several weeks' incubation, is the organism very abundantly present. The milk retains its normal fluid condition, although its reaction soon becomes slightly acid; after a week the acidity of the milk is pronounced. After several weeks, owing to further increase of acidity, some minute flocculi of coagulated casein may be noticed, but the general condition of the milk does not materially alter however long the incubation may last.

A very remarkable difference exists between cultures in milk and in other fluid media. It consists in this, namely, that the growth in milk remains alive even after lapse of several months (the tubes after two or three weeks in the incubator being removed and kept at an ordinary temperature in order to prevent them from drying up); for inoculations started from milk tubes kept several months, yield successful subcultures. Whereas, in broth peptone tubes, or in other fluid media, kept for some weeks (3, 4, or more weeks) the growth apparently becomes void of life; at any rate new subcultures cannot be established from it.

its microscopic characters.

Microscopic specimens made of the growth from fluid media, show it to consist of dumb-bell micrococci, diplococci, but chiefly of chains, streptococci, composed of 4, 6, 8, 12, 16, and more elements serially arranged. The longer the incubation the longer the chains; but already after 24 hours most of the organisms appear as short streptococci; and the longer the chains the more twisted and curved are they. I have had tubes of broth peptone in which after a week the whole growth had settled down to the bottom in the shape of a tenaceous loose or fluffy moss, the supernatant fluid having become quite clear. This moss was entirely made up of threads of enormous length, much twisted, coiled, and convoluted. But in all parts the threads were beautifully made up of spherical micrococci. Also in milk the chains or streptococci are the chief representatives of the organisms, though there are present in addition numerous diplococci.

Figure 9.

The individual elements in the diplococci and streptococci are spherical, on an average measuring in diameter 0·0006 to 0·0008 m.m. There are, however, chains, in which all or at any rate many of the elements are strikingly larger than above noted. There are chains too in which one or another element is larger than the rest and shows a commencing, sometimes a nearly complete, vertical division into two smaller elements, which are, therefore, placed side by side *laterally*. As a rule the elements divide transversely, *i.e.*, they are placed end to end in the

long axis of the chain and thus the chain becomes elongated; but the division just referred to is a longitudinal division, whereby at a particular point in the chain the elements come to lie not end to end, but side by side. In some chains this longitudinal division involves two or three neighbouring elements, and as a result we find particular chains, which in their middle part show smaller elements in a double file. Another curious result of such division is the production of a shorter or longer chain of small elements budding out laterally like a branch from a chain composed everywhere of large elements, except at the point of branching where the elements are as small as those of the lateral chain. In some chains the terminal element is oval and considerably larger than its fellows; these terminal buds are sometimes slightly pointed at the free end.

In the diplococci and in the chains the elements are placed closely, end to end: there is hardly any intervening interstitial substance noticeable. But I have seen in broth peptone, and in Agar-Agar cultures, chains of immense length, extending in a wavy, twisted, and curled fashion through several fields of the microscope, where there was an appreciable bridge of an interstitial substance between the elements. This interstitial substance stains less deeply in dyes than the cocci themselves. I have before me preparations of this streptococcus from broth peptone and Agar-Agar cultures, the latter three to four weeks old. Some of these streptococci are composed of 6, 8, 16, 20, 30 elements; others are of a length exceeding two and three fields of the microscope, even under a magnifying power of only 300 (Zeiss Oc. 3, Obj. D.); such chains contain several hundred elements. Some of the chains are in places regularly wavy or even spirally twisted, at other places less curved or almost straight. Most of the chains are in reality made up of diplococci, the elements of each diplococcus in the chain being quite close, while there is an appreciable bridge of a faintly stained substance between the several diplococci. Another remarkable feature in these preparations is the numbers of shorter or longer branched chains. These branchings are not to be confounded with mere crossed chains, but are real lateral or terminal branchings resembling very much a cladothrix. Their mode of origin has been already described as produced by a vertical division of one of the middle elements, sometimes of a terminal element, followed by a continued normal transverse division of the new elements.

Figure 10.

(*c.*) *On nutrient gelatine* the character of the growth is this:—if the inoculation with the organism is made in a channel passing from the surface into the depth, *i.e.* with a platinum wire or the end of a capillary glass pipette, there is noticeable after the lapse of from two to three days (the temperature of the incubator being 19° C.) a first trace of the growth in the shape of an opaque line indicating the channel of inoculation. Under a magnifying glass this line is seen to be composed of very minute spots closely placed side by side. In the next few days the line becomes thicker, and then even to the naked eye appears composed of whitish granules or droplets. Under a magnifying glass these are now more distinct because larger; they are round, and in some places along the line are more closely placed than in others, and the line or inoculation channel is not merely a single file of the droplets or granules, but a streak of them several abreast; the thickness or breadth depending of course also on the breadth of the inoculation channel originally made. As development proceeds the streak broadens, the granules or droplets becoming more numerous and larger, but their size never exceeds, and rarely reaches, that of a small pin's head; in cultures several

Figure 8 (1 & 2).

weeks or months old the individual granules when not placed too closely can, owing to their opacity, just be made out with the naked eye, where very closely placed, they can only be recognized as discrete granules by aid of a magnifying glass. The gelatine is not liquefied by the growth.

If the organism be sowed on the surface of the gelatine, in a line, or if a small droplet of culture fluid be allowed to spread out on the gelatine, after 4, 5, or more days, the growth is noticeable as a whitish film, composed of discrete minute translucent droplets or granules, in some places lying closely, in others more apart. Under a magnifying glass the granules at the margin of the film are flatter, larger, and their outline sometimes more irregular than the others. The film increases in breadth, but always remains a film, *i.e.*, very thin ; and even after several months of incubation it does not exceed the area of original inoculation by more than one or two millimetres.

If a large drop of culture fluid has been allowed, on inoculation, to spread out over the surface of the gelatine, the film will, of course, even after a few days' incubation, be larger than if the inoculation has been made along a line ; but in all cases the growth is made up of discreet granules, in some places more closely placed than in others, in which case they are recognizable only under a lens as granules ; in other places where they are placed farther apart they are recognizable as such by the naked eye. The granules are more opaque the larger they are. If the granules are very minute, but closely placed, the film has to the naked eye an irridescent appearance in reflected light, and a more bluish tint in transmitted light. Under a lens, in reflected light, the film appears of a slightly brownish tint.

Figure 8 (3).

(*d.*) *On Agar-Agar mixture and solid blood* serum the appearances are the same as on gelatine. On solid serum the marginal granules of the film are perhaps flatter and larger than on other solid media.

(*e.*) *In fluid blood serum kept at* 35°—37° *C.* the growth does not become copious ; it is always in the shape of minute flakes and granules floating and suspended in the deeper layers of the fluid material.

Figure 8 (4).

(*f.*) *In nutritive gelatine kept at* 35°—37° *C.* (*i.e.*, in a fluid state), the growth after several days appears as minute flocculi or granules, which as development proceeds increase in number and size.

In all these culture media the granules or droplets of the growth are due to masses and convolutions of the streptococcus, and the number of these determine the size of the granules.

Experiments on Animals with the Streptococcus from the diseased Tissues.

Administration of matters of cultures:

(*a.*) I first *inoculated subcutaneously* in the region of the groin five sheep (1, 2, 3, 4, 5), each animal receiving about 10 minims of a culture of the organism on Agar-Agar mixture. The sample of the growth used for inoculation had been scraped off from the surface of the Agar-Agar mixture and distributed in a little sterile salt solution, so as to make an infusion of the colour of thin cows milk : this infusion was crowded with the organisms. After lapse of five days sheep 1 and 2 were re-inoculated.

to sheep;

(*b.*) After further lapse of 12 days, *i.e.*, 17 days subsequent to the primary *subcutaneous inoculation*, all five of the sheep were *fed* with a mixture composed of culture of the streptococcus in milk and culture of the same organism in broth. The culture thus used for *feeding* teemed with the organisms, and each animal received by the mouth about 5 CC. of the mixed cultures.

Their temperatures duly taken each evening before and after inoculation were as follows :—

Temperatures of Sheep.

On evening of	1.	2.	3.	4.	5.
Day preceding inoculation	39·4	39·8	39·	39·4	38·7
1st day of experiment (inoculation in the morning).	39·2	41·	39·5	39·8	39·9
2nd day	39·5	40·	39·5	39·9	39·4
3rd „	38·9	39·4	39·3	39·6	40·3
4th „	39·6	39·5	39·4	39·8	39·9
5th „	39·2	39·3	39·1	39·5	39·5
6th „ (Sheep 1 and 2 having been re-inoculated in the morning).	40·9	41·	39·3	39·3	39·3
7th day	40·2	39·9	39·3	39·4	39·4
8th „	40·6	39·6	39·3	39·6	39·5
9th „	39·8	39·6	39·4	39·7	39·2
10th „	39·4	39·8	39·4	39·5	39·4
11th „	39·5	39·6	39·3	39·6	39·5
12th „	40·1	40·4	39·4	39·7	39·2
13th „	39·8	39·7			
14th „	39·9	41·1			
15th „	39·6	39·5			
16th „	39·5	39·7			
17th „	39·6	39·5			

After feeding the temperatures remained normal.

It is seen from the above table that in some but not in all the animals there was rise of temperature on the evening of the day of the inoculation. This rise was pronounced in sheep 2, and was also very pronounced at the second inoculation of sheep 1 and 2. The feeding of all five sheep with streptococcus was repeated on three subsequent occasions, but without obvious result.

I next tried the effect of feeding with the streptococcus sheep which had not previously been inoculated with the organism :—

(*c.*) Two sheep (6, 7) were fed with a mixture made up of growths of the streptococcus in :—(*a*) Agar-Agar, (*b*) milk, and (*c*) peptone broth. Each animal received by the mouth about 5 CC. of the combined cultures. On the sixth day sheep 7 showed great tenderness of right hind foot ; the animal walked lame, and this lameness increased strikingly during the next two days. On the eighth day, examination of the right hind foot revealed a large swelling of the size of a pigeon's egg, just above and in front of the hoof cleft ; in addition there was a distinct blister of the size of a sixpence laterally just above the hoof ; and lastly, the skin of the cleft was very white, tumid, and painful, and at its upper margin (*i.e.*, where it is in contact with the hoof) the epidermis was in some places distinctly blistered, in others suffused with blood. On the tenth day the conditions were about the same as before, except that in the cleft where the skin passes into the hoof there was commencing ulceration.

The right forefoot at this date showed great tenderness, and on examining it, the skin of the cleft was tumid, white, and showed in some places blisters, in others commencing ulceration ; the latter especially noticeable along the upper margin, that is where the skin passes into the hoof.

On the 13th day the swollen condition of the right hind foot just above the hoof was still very marked, and the ulceration of the skin in the cleft was advancing. On this day also the left fore foot showed great tenderness, and in the cleft the skin was white and tumid, and showed commencing ulceration. On the 17th day this condition had become further advanced, the ulceration had extended all along the upper margin of the cleft where the soft skin is in contact with the hoof. The sheep's breathing was rapid. At the end of the fourth week the animal was still lame, but the condition of the fore feet and of the right hind foot showed much improvement. At the end of the sixth week the lameness had disappeared and the anatomical condition of the feet appeared normal.

The temperature of these sheep showed no definite change during the incubation and outbreak of the illness as will be seen from the subjoined table :—

Temperature on -	Sheep 6.		Sheep 7.	
	Morning.	Evening.	Morning.	Evening.
Day before feeding -	39·6	39·5	38·8	39·4
Day of feeding (the feeding being administered at mid-day).	39·6	39·7	39·5	39·6
1 day after feeding -	39·4	39·8	39·3	39·3
2 „ „ -	39·3	39·6	39·4	39 4
3 „ „ -	39·5	39·5	39·4	39·6
4 „ „ -	39·4	39·5	39·2	39·5
5 „ „ -	39·4	39·6	39·2	39·5
6 „ „ -	39·5	39·	39·	39·4
7 „ „ -	39·2	39·5	39·7	39·6
8 „ „ -	39·2	39·2	39·	39·1
9 „ „ -	39·1	39·5	39·2	39·7
10 „ „ -	39·9	39·7	39·	39·8
11 „ „ -	39·1	39·8	39·7	39·7
12 „ „ -	39·6	40·	39·	39·2
13 „ „ -	39·3	39·4	38·9	39·2

(*d.*) Sheep 6 which had showed no response to the first feeding, was now a fortnight later again fed this time *per nasum* with the same amount as above of a culture of the streptococcus in broth peptone and gelatine, but with no result. The same animal was further fed *per nasum* with the streptococcus on four subsequent occasions, but without response.

(*e.*) Two additional sheep (8, 9) which had not been previously inoculated with streptococcus were fed *per os et per nasum* with a 5 c. c. culture of the streptococcus, but with no response. Eight days later they were fed a second time in like manner, but with no result. Thirteen days after the last experiment they were fed a third time with a a 5 c.c. culture of the streptococcus in milk and Agar-Agar mixture. Their temperatures during the course of these feedings, were as follows :—

Temperature on -	Sheep 8.		Sheep 9.	
	Morning.	Evening.	Morning.	Evening.
Day before feeding -	39·1	39·4	38·8	39·2
Day of first feeding (feeding taking place at noon).	39·6	39·5	39·1	39·
	39·	39·	39·4	39·2
	39·4	39·6	38·8	39·4
	39·2	39·4	39·1	39·4
	38·6	39·4	39·3	39·
	39·	39·4	38·8	39·1
	38·8	39·2	39·2	39·
	39·1	39·4	39·1	39·3
Day of second feeding -	39·2	39·8	39·	39·4
	39·3	39·6	39·	39·5
	39·4	39·5	39·4	39·6
	39·	39·4	40·	39·8
	39·3	39·9	39·3	39·2
	38·9	39·	38·9	39·2
	38·7	39·4	39·	39·2
	38·8	39·	39·4	39·2
	39·4	39·2	38·8	39·4
		39·3		39·7
	39·2	39·2	39·7	39·4
	39·	39·3	39·2	39·6
	38·6	39·1	39·2	39·5
Day of third feeding -	38·7	38·9	38·9	39·4
	39·	39·5	38·9	39·2
	39·	39·3	38·8	39·
	38·9	39·7	39·	39·6
	39·1	39·3	38·9	39·4
	39·	39·6	38·9	39·8
	39·2	38·8	39·	39·
	39·	39·5	39·1	39·1

The temperature continued to be taken for many weeks, but no alteration was perceptible.

On the sixth day after the last feeding, however, sheep 9 showed lameness; and on examination the right hind foot and both fore feet were found very tender; the skin of the cleft was white, tumid, and on the upper margin where the soft skin passes into the hoof there was blistering and in some places commencing ulceration.

On the eighth day sheep 8 also showed slight lameness, but on examination nothing definite could be discovered on her feet. Her slight lameness persisted for the next two days and then passed off. But in sheep 9 the lameness increased to such an extent that the animal could walk only with great difficulty. On examining her feet on the 10th day, the skin of the cleft along the whole extent of the upper margin (*i.e.*, where the soft skin passes into the hoof) showed ulceration. This animal was killed on the 11th day.

On opening the chest, small nodules, isolated and in groups, were found dotted over the surface and throughout the lung tissue; some of the nodules were not larger than a small pin's head, others were as large as a millet seed or even a small pea. Some were grey, others yellowish; all were firm and felt gritty. These were inflammatory nodules due to the presence of strongylus filaria, which is not uncommon in sheep. The bronchial glands were much swollen and were permeated with the same kind of nodules as the lungs. The spleen showed hæmorrhagic spots in the capsule. No other change in the internal organs.

(*f.*) Sheep 6 and 8, and in addition three calves (10, 11, 12) were now sought to be infected by introducing streptococcus of fresh cultures, in to calves;

milk and Agar-Agar, directly into the cavity of the trachea; each animal received a Pravaz syringe full of culture fluid teeming with the streptococcus. No result. The temperatures of the experimental animals, before and after injection of the micro-organism, did not differ; the temperature after the injection being taken morning and evening for many days.

to pigs;

(*g.*) Two pigs were inoculated with about 1 Pravaz syringe full of the same streptococcus in the subcutaneous tissue of the groin; they did not become at all ill. The same animals were subsequently fed* *per os et per nasum* on four separate occasions, but with no result.

to guinea-pigs.

(*h.*) Two guinea-pigs were inoculated subcutaneously with the streptococcus; no result. Four fresh guinea-pigs were inoculated subcutaneously; no result. Two additional guinea-pigs were fed *per os* with the same streptococcus; one died on the 14th, the other on the 17th day. In both cases the stomach was found inflamed; at its pyloric end there was an ulcer that had perforated into the peritoneal cavity.

(*j.*) Two guinea-pigs were now fed with a recent cultivation of the streptococcus in broth peptone and milk. One died on the 20th day, the other was killed. The latter on examination appeared quite normal; the former showed an abscess between the wall of the pyloric end of the stomach and the abdominal wall; the left lobe of its liver was adherent to the abscess, and in this lobe were several necrotic patches. The lungs were congested.

(*k.*) Two guinea-pigs were fed from a different cultivation of the streptococcus; no result.

(*l.*) Four guinea-pigs were fed from fresh cultivation of the streptococcus; no result.

(*l.*) Four guinea-pigs were fed with fresh cultivation of the streptococcus in milk, broth peptone, and Agar-Agar mixture; no result. These culture tubes were the same as used successfully with sheep 7.

We see, then, from these experiments—

Results:

(1) that five sheep, two pigs, and six guinea-pigs, inoculated with the streptococcus did not suffer any noticeable illness:

(2) that injection of a relatively large quantity of the streptococcus directly into the cavity of the trachea in the case of two sheep and three calves failed to induce in these animals foot-and-mouth disease:

But that:—

(3) Feeding of four sheep with cultures of streptococcus induced in two of them the typical disease on the feet; a third animal showing lameness, without other evidence of having contracted the malady; while the fourth remained well. On the other hand, certain guinea-pigs fed with the same streptococcus did not suffer foot-and-mouth disease, but three of them died with disease in the stomach which seemingly was of like nature in all cases.

One point, however, which is very puzzling is this, namely, that as regards the sheep 8 and 9, feeding with the streptococcus had to be repeated three times before one became infected.†

This difficulty in infecting the sheep is capable of explanation in one of two ways; it must have been due to want of virulence in the cultures,

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* *Feeding means always:* about 5 c.c. of a mixture of cultures in Agar-Agar, milk, and broth peptone, unless otherwise stated.

† I may remind the reader that in experiments made some years ago by Sanderson and Duguid infection of one out of several cows was not achieved until the infective material (hay steeped in saliva of the mouth of a diseased cow), had been several times rubbed over the mucous membrane of their mouths.

or to insusceptibility of the animals fed with them. As regards the cultures:—If it be granted that the organism with which we are dealing is the actual infective material of foot-and-mouth disease it is difficult to understand why the cultures should not have been uniformly infective. It is essential therefore to state here, that in every instance a culture of streptococcus used for experiment on an animal was at the same time used for starting subcultures in Agar-Agar and gelatine media, and that it always yielded in these media characteristic and typical growth of the organism. It is further necessary to state that the mixed cultures of the organism used for experiment on both sheep were of various ages; some were quite recent or only a few days old, others were one, two, three, or four weeks old.

It might be suggested that possibly in some of the instances where the result of the feeding was negative, the cultures used contained the streptococcus in an attenuated form; and I cannot adduce anything to substantiate or to disprove such assumption. But upon the whole I am inclined to think that failure, when it occurred, was to be attributed to the animal itself. Whether, as appears from the known facts in regard to the natural occurrence of the disease, some animals are *per se* less susceptible of the infection than others; or whether the animal's digestive organs must, for successful infection, be in a particular but undetermined condition, are questions which require further and special investigation.

of feeding experiments;

This much, however, appears probable, that as in the disease naturally acquired so in the disease artificially induced, the only efficient introduction of the virus to the animal body is by way of the digestive organs. That infection does not in all probability take place by way of the respiratory organs, seems shown by the negative experiments I have recorded in regard of calves in which the streptococcus in very large quantities had been introduced *per tracheam*. And it likewise appears that by subcutaneous inoculation of the organism nothing like foot-and-mouth disease has so far been produced in the animals experimented on.

to sheep;

In reference to the success of feeding experiments there can be no question that the disease affecting the feet of sheep 7 and 9 was typical foot-and-mouth disease; the incubation, the symptoms, and the anatomical characters of the malady can leave no doubt on the subject. As regards anatomical characters, microscopic examination of the skin of the cleft in sheep 9 showed conclusively those of foot-and-mouth disease as displayed in the skin of the cleft of the Ampthill sheep. My notes on sheep 9 run thus:—

"Throughout the whole extent of the cleft, the corium and the papillæ are much infiltrated by round cells; towards the margin of the cleft, *i.e.*, where the soft skin is in contact with the hoof, the infiltration of the superficial corium and of the papillæ is most pronounced. Here the papillæ in their whole length are much enlarged owing to the engorged vessels and the numerous round cells. Near the stratum corneum the anatomical change involves the formation of cavities, filled with extravasated blood, lymph, and exudation cells. In connexion with these we find numerous small cavities formed in the epithelium itself owing to the penetration into it from the papillæ of blood, lymph, and exudation cells; the cells of the epithelium under this process have degenerated, and as a result we find groups of small cavities separated by the remnants of the epithelium; or larger cavities are produced by the confluence of several small ones. But the chief cavities are formed by the enlargement of the papillæ in the upper layers of the stratum Malpighii. In this region we find networks of broader or narrower channels between the epithelial cells, containing red blood corpuscles and round cells, and these channels

Figures 5, 6, & 7.

and their contents are in direct communication with the papillary cavities above mentioned. In a few places the larger superficial cavities are in direct communication with the free surface, owing to the stratum corneum having given way." We thus see the anatomical characters described as belonging to the vesicle on the foot of the sheep of Ampthill, repeated in all details in regard of sheep 9. As has been already mentioned, both fore feet and the right hind foot of this sheep 9 showed the disease. Neither in this animal nor in sheep 7 was there any disease in the mouth, but it is well known that a large percentage of animals, and especially sheep, suffering from the disease are affected only on the feet. As matter of fact amongst the sheep at Ampthill affected with the disease there were only a few that had ulcerations in the mouth; in the majority of those examined the muoth was absolutely free from disease.

The sheep 7 and 9, which displayed the typical disease on the feet, gave no evidence of decided general disturbance in health. It is true that when the disease appeared in their feet and as long as it lasted the animals were quiet and did not move much. The circumstance, however, is easily accounted for seeing that they were lame, and that when moved, or forced to move, the tenderness of their feet must have caused them pain. There was, however, never any noticeable falling off in their feeding and ruminating power. Sheep 7, at the end of the fourth week, had some slight looseness of the bowels, but this passed off in a couple of days; similar looseness of the bowels occurred also at the same time in another sheep that was not ill with foot-and-mouth disease.

As regards the sheep that did not become attacked by foot-and-mouth disease after feeding with the streptococcus, their escape need not be matter for surprise considering that under natural conditions, as for instance in the outbreak at Ampthill, not more than 25 or 30 per cent. of the flock take the disease, however closely intermixed with animals suffering under it.

Now the cultures which when administered by the mouth to sheep had induced in one-half of them disease of the feet identical with that occurring in foot-and-mouth disease, were subcultures of the very same streptococcus which had been derived from the vesicle of the Ampthill sheep; and there can be no question that they contained the streptococcus and nothing but the streptococcus, since some of them were 15, while others were as many as 30 "removes" distant from the original source. This streptococcus, therefore, may for practical purposes be regarded as the demonstrated virus of foot-and-mouth disease.

If further proof be wanted of this it is forthcoming as follows:—

Sheep 7 which, as has been already mentioned, had become subject to the disease of the feet after feeding with the streptococcus, had, on the eighth day, a large swelling just above the cleft between the claws. The skin over this swelling was shaved, well washed with soap and water, and then washed with a strong solution of perchloride of mercury. The superficial layer of the epidermis having been removed with clean sterile scalpel, the pointed end of a freshly drawn-out capillary glass pipette was pushed into the depth of the corium, and several drops of a clear lymph collected therefrom after the fashion already described. With this lymph, inoculations were at once made of test tubes containing nutrient gelatine, Agar-Agar mixture, and blood serum. Cover glass specimens were also made and stained in the usual way. The culture tubes inoculated showed after a few days exactly the *same characteristic growth of the streptococcus* that had been obtained from the vesicle of the sheep at Ampthill affected with the natural disease. Sub-cultures were then carried on through many generations, in gelatine,

Agar-Agar, serum, milk, broth, &c., and the same typical growth was obtained in all of them. Similarly examination of the cover glass specimens of this same lymph proved the existence in it of diplococci and a few short chains of micrococcus of the same size and aspect as those obtained from the sheep at Ampthill.

There can be then no doubt whatever that the typical streptococcus was present in the lymph of the swelling of the induced disease in the foot of sheep 7. It was present too in the diseased tissues of the feet of sheep 9. Microscopic sections stained with gentian violet, with methyl blue, and with eosin, showed in the infiltration of the superficial corium, in the enlarged papillæ, and in the cavities of the upper parts of the Malpighian layer (both in the large cavities formed from papillæ as well as the small ones formed between the epithelial cells), abundance of the diplococci, and occasionally also short streptococci similar to those described as existing in the vesicle of the Ampthill sheep. As a matter of fact the sections of the diseased skin of sheep 9 were in this respect even more definite and unmistakeable than those of the vesicle of the Ampthill sheep.

Of the three guinea-pigs that died in consequence of feeding with the streptococcus, two had similar diplococci and a few short chains in their blood. This blood was inoculated into four other guinea-pigs, but without any result. The third guinea-pig of the first series, *i.e.*, the one having an abscess between the stomach wall and abdominal wall, had numerous diplococci and chains in the pus of this abscess; but subcutaneous inoculation of this pus into two guinea-pigs produced no result whatever.

to guinea-pigs.

To sum up then this part of the inquiry:—We see that (*a*)microscopic examination of the diseased skin of the feet of this sheep 9, which had been artificially infected with a sub-culture of the streptococcus many "removes" separate from its original breeding ground in the vesicle of the Ampthill sheep, proved the identity as regards anatomical details of the induced malady with that of the Ampthill sheep affected naturally with foot-and-mouth disease; (*b*) one and the same micrococcus was obtained from the lymph of sheep 7 artificially infected with a cultivation of the above micrococcus and from the lymph of the Ampthill sheep; and (*c*) the tissue of the diseased skin of sheep 9, which had been artificially infected, contained identically the same micrococcus as was demonstrated to exist in the diseased tissues of the Ampthill sheep.

Summary.

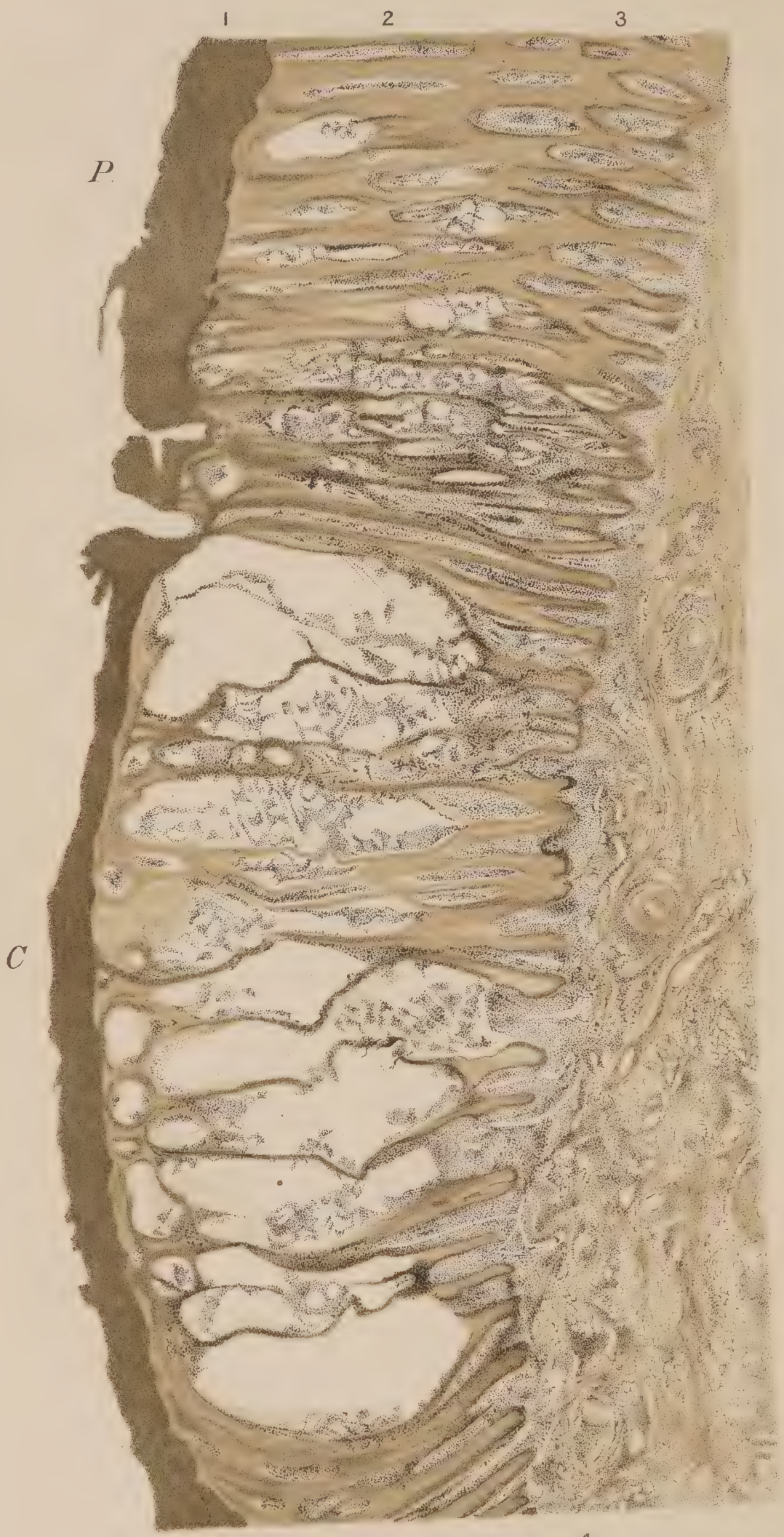
Herewith are fulfilled all the conditions required for a demonstration of the causal connexion between a given micro-organism and a given infectious disease, viz.:—demonstration of the organism in the diseased tissues of the animal body affected with the malady; successive sub-culture many times repeated outside the animal body of the demonstrated organism; successful production in another animal body of the identical malady by administration to it of the organism of such sub-cultures; and identification in the diseased tissue of the subject of this artificially induced malady of the very same organism which had been in the first instance associated with the given infectious disease.

Finally, I have to note a further and perhaps highly important indication arising from these investigations. It will be remembered that in all cases in which subcutaneous inoculation of sheep (1, 2, 3, 4, and 5) had been practised, subsequent repeated administration of the virus by way of the digestive organs failed to produce any result, though in these experimental feedings the same cultures were employed that were used in two successful experiments on sheep 7 and 9. Now, bearing in mind that as regards *feeding per se*, we can point to two positive

Indications for further inquiry.

results out of four experiments on sheep not previously inoculated; it is to be inferred that the negative result of repeated feeding experiments on those first five sheep was, in all probability, due to their having been rendered refractory by the previous subcutaneous inoculation. And this is borne out to a certain degree by the fact that the two pigs subcutaneously inoculated and then fed with active virus on four different occasions wholly escaped foot-and-mouth disease, although it is well known that pigs have a greater susceptibility to the disease than even sheep. If this should really be found to be the case, viz., if a previous subcutaneous inoculation with the virus, though it does not effect any conspicuous disturbance of the general health, renders the animals experimented on thenceforward insusceptible to foot-and-mouth disease, a means will have been found to protect some animals at least against the virulent form of this disorder. But for a completely satisfactory settlement of the question, cattle as well as sheep require to be experimented on, since cattle are the most susceptible of animals as regards foot-and-mouth disease. So far I have not had an opportunity of extending my experiments in this direction.

Fig. 1.



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FOOT-AND-MOUTH DISEASE.

PLATE I.

Fig. 1.

Vertical section through the vesicle in foot-and-mouth disease of sheep. Magnif. power × 25.

The vesicle was situated at the boundary between the hoof and soft skin.

C. Central portion of the vesicle.

P. Peripheral portion of same.

1. Horny layer.
2. Superficial and middle layers of the stratum Malpighii.
3. Deep layer of the stratum Malpighii.
4. Superficial layer of the corium much infiltrated with round-cells.

The cavities forming the vesicle are clearly seen to be derived from the enlarged papillæ; the infiltrated tissue of the superficial corium passing, in the central part of the vesicle, directly into the tissue contained in the cavities.

FOOT-AND-MOUTH DISEASE.

PLATE II.

FIG. 2.

Vertical section through a vesicle that has already burst; from the region of the cleft between the hoofs. Magnif. power × 25.

1. Horny layer, stained pink.
2. Stratum Malpighii with the papillæ.
3. A hairshaft, keeping in position the covering layer of the original vesicle.
4. Coagulated lymph contained in the original vesicle.
5. A hair and sebaceous follicle.

The superficial corium and the tissue of the papillæ are much infiltrated with round-cells.

Fig. 2.

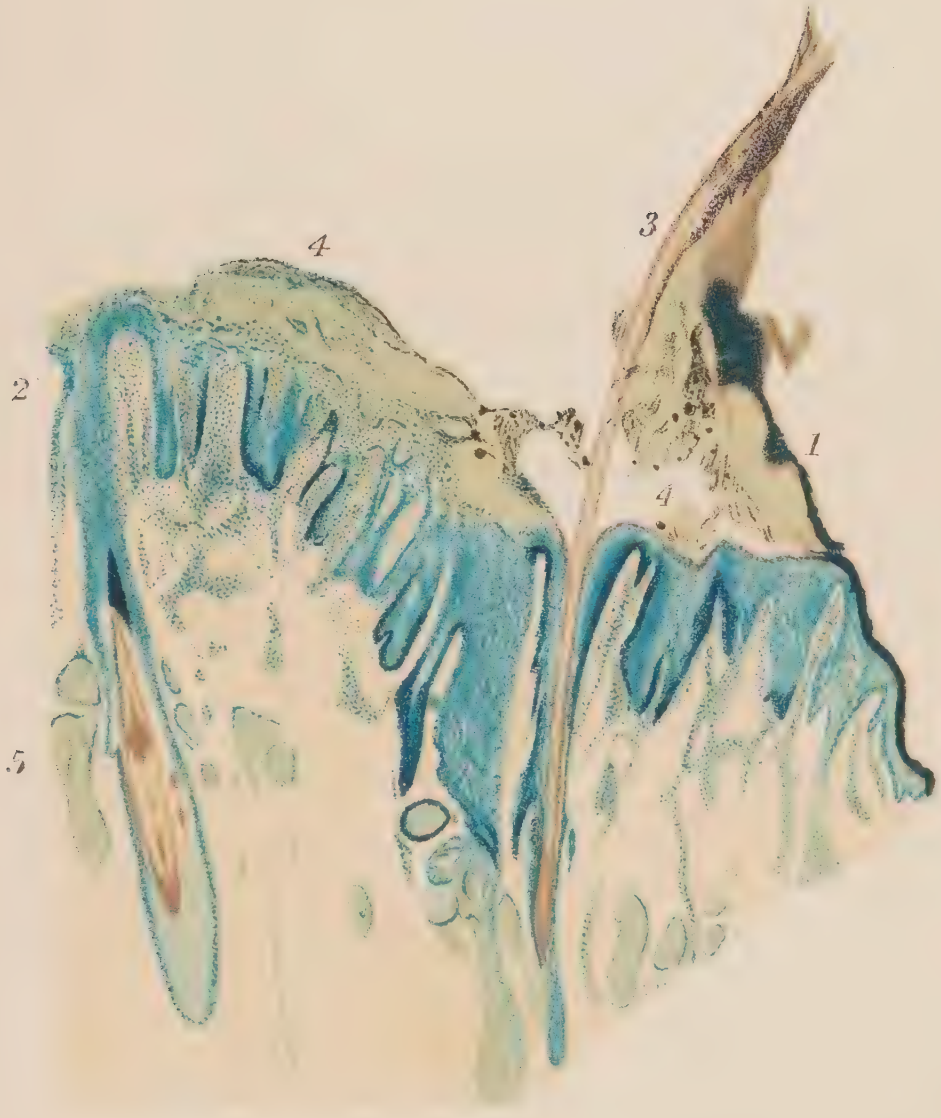

Fig. 3.

M. H. Lapidge del.

Fred.k Dangerfield, Lithographer, Londo[illegible]

FOOT-AND-MOUTH DISEASE.

PLATE III.

Fig. 3.

Vertical section through a small ulcer of the mouth in foot-and-mouth disease of sheep. Magnif. power about 40.

1. Horny layer.
2. Stratum Malpighii and papillæ, their tissue much infiltrated with round-cells.
3. The centre of the eruption, where the infiltrating matters exude on the free surface.

FOOT-AND-MOUTH DISEASE.

PLATE IV.

Fig. 4.

Part of a section, the same as shown in Fig. 1, but magnified 100.

1. Horny layer of the epidermis.
2. Stratum Malpighii, not exhibited.
3. A papilla infiltrated with round-cells.
4. Papillæ, much enlarged and transformed into cavities.
5. Upper part of a papilla, much enlarged and containing (coagulated) lymph.

Fig. 4.

H.Lapidge del. Dangerfield Lithocraph.er London.

Fig 5

M.H. Lapidge del.

Dancerfield, Lith. 22, Bedford St. Covent Garden.

FOOT-AND-MOUTH DISEASE.

PLATE V.

FIG. 5.

From a section (slightly oblique) through the eruption—at the boundary between the soft skin in the cleft and the hoof of sheep—artificially produced by feeding the animal with a cultivation of the streptococcus. Magnif. power about 40.

1. Horny layer.
2. Superficial layers of the stratum Malpighii, seen obliquely cut.
3. Deep layer of the stratum Malpighii and papillæ, also cut obliquely.
4. Cavities, filled with round-cells and blood corpuscles, in the superficial layer of the stratum Malpighii.
5. Enlarged papillæ continuous with the above cavities.

FOOT-AND-MOUTH DISEASE.

PLATE VI.

Fig. 6.

Part of a preparation similar to that shown in Fig. 5, but magnified about 100.

1. Superficial layers of the stratum Malpighii; its epithelial cells not exhibited.
2. Cavities, filled with round-cells.
3. These latter extending into canals formed between the epithelium cells.

Fig. 7.

Part of the same section as represented in Fig. 6. Magnif. power about 200.

1. A cavity is shown in the superficial layer of the stratum Malpighii. The epithelial cells of this latter are not shown; the cavity is filled with round-cells, extending (at 2) into channels burrowed between the epithelial cells of the stratum Malpighii.
3. Similar channels, filled with the micrococci.

Fig. 6.

Fig. 7.

Fig. 8.

1

2

3

4

FOOT-AND-MOUTH DISEASE.

PLATE VII.

Fig. 8.

Artificial cultivations of the streptococcus of foot-and-mouth disease, in test tubes.

1. On the surface of nutritive gelatine; natural size.
2. The same seen under a magnifying glass.
3. On the surface of Agar-Agar mixture seen under a lens.
4. In gelatine, kept liquefied for a few days, then allowed to set and kept so afterwards.

The character of the growth is well marked in each instance.

FOOT-AND-MOUTH DISEASE.

PLATE VIII.

Fig. 9.

From a microscopic specimen of an artificial cultivation of the streptococcus in broth, after three days' growth at 36° C.

a. Diplococcus.

b. Short chains.

c. Complex chains, due to longitudinal division of the cocci of a chain.

Magnif. power about 1250.

Fig. 10.

From an artificial cultivation of the streptococcus of foot-and-mouth disease in Agar Agar mixture, after several weeks' growth. Magnif. power about 1250.

a. Simple streptococcus; here and there in it a coccus conspicuously larger than the rest.

b. Branched streptococcus.

c. Streptococcus, with indication of longitudinal division of the cocci.

Fig. 9.

Fig. 10.

No. 2.

Some Points bearing on the Etiology of Tuberculosis; by E. Klein, M.D., F.R.S., and Mr. A. Lingard, M.R.C.S.

I. *On the Infective Power of Tubercular Deposits.*

In previous reports (1883 and 1884) it has been shown that in tuberculosis artificially induced in guinea-pigs, whether with matter from a human or from a bovine source, tubercle bacilli, such as are demonstrable in the customary manner by staining, are not found in all the resulting tubercular deposits. From many such deposits that are recent tubercle bacilli often are absent, though, as a rule, they are present in varying numbers in those deposits that have entered the state of caseation.

Now it is generally believed that tuberculosis is caused solely by materials containing tubercle bacilli having gained entrance to the animal body; that it is *not* producible by material which does not contain these bacilli. Accordingly we set ourselves to test the validity of this hypothesis, and in certain experiments inoculated into guinea-pigs material of tubercular deposits in which by no known method of staining were any tubercle bacilli discoverable.

The material that we used was the liver of guinea-pigs that had been infected with tuberculosis. In most instances of tuberculosis artificially induced (by subcutaneous inoculation) in guinea-pigs, the liver at an early stage of the disease is, as is well known, the seat of tubercular deposits; the whole organ is uniformly permeated by small roundish or irregular whitish spots, streaks, and patches, isolated in some parts of the organ, confluent in others. In such liver, even at early stages of the disease, there are present spots and patches which have entered upon a state of caseation; but a good many of the small spots and streaks are very recent tubercular deposits, made up of round cells, in which no tubercle bacilli whatever can be discovered. Sections were made of the fresh liver, portions being chosen which to the naked eye did not contain any caseating deposits. Some of these sections were then stained and examined microscopically, and if the characteristic tubercle bacilli were not to be found in them, companion sections were mashed up with a few drops of sterilised saline solution and subcutaneously injected into healthy guinea-pigs. As a result of these inoculations in all instances ordinary general tuberculosis was produced in the guinea-pigs, with the well-known tubercular deposits in lungs, liver, spleen, and lymph glands. Among these deposits many were found caseous, and these contained the characteristic tubercle bacilli.

The most plausible explanation of this phænomenon appears to be that the sections used for inoculation did really contain tubercle bacilli in some form or other, although no such bacilli in any form could be discovered in companion sections stained and examined microscopically according to the best methods known. Our reason for adopting this explanation is that we find it impossible to affirm that in a given lump of tissue there is not any *caseating spot*,—any spot from which tubercle bacilli are positively and unequivocally absent. The tubercular deposits of the liver were of such various stages, so intermixed and blended, that it is quite impossible to say of any particular section that it does not contain any caseating matter. And if this be not sufficient reason for declining to assert that tubercle are absent, there remains the consideration that the spores of tubercle bacilli are not to be detected by any method of staining hitherto adopted.

[We do not consider certain granules and protoplasmic accumulations, seen in many stained tubercle specimens, to be spores of tubercle bacillus, as has been believed by some observers. These, neither in aspect nor nature, can be regarded as anything more than young, growing bacillary elements in a chain of bacilli; and they do not at all correspond to what are generally considered as spores in some other bacilli, *e.g.*, bacillus, anthracis, and subtilis.]

This explanation has appeared to us to form a bar to further inquiry. What may be the modus operandi of bacillar life, whether it be injurious per se or through some chemical product of its own, whether tubercle bacilli are operative by direct general infection of the body, or by indirect local operations,—must remain open questions so long as we have the above strong reasons for thinking that bacilli themselves in some form or other, and capable of producing their specific biological results, may exist without our being able to detect them microscopically; and the only conclusion that we have at present to record is this :—

We conclude from our experiments that sections of tubercular deposits in which, on the most careful microscopic examination by the most approved methods, no tubercle bacilli can be discovered, possess, nevertheless, the power of producing tuberculosis with appearance of tubercle bacilli in the resulting caseating deposits, and that therefore there must have been present tubercle bacilli, or spores of tubercle bacilli, in the sections that we used for our inoculation.

II.—*The relation of Tuberculosis in Fowls to Human and Bovine Tuberculosis.*

It is well known that fowls are sometimes spontaneously affected with tubercular disease. In these cases the liver and mesenteric glands are found greatly enlarged from tubercular deposits, some of which are caseous and contain tubercle bacilli.

It has been repeatedly stated that poultry feeding on materials accidentally contaminated with human tubercular sputum easily become affected with tuberculosis. If this be really the case, the practical importance of such observations cannot be too highly estimated; for if fowls can be made tubercular by consuming human tubercular matter such fowls in their turn may be able to infect the human subject with the disease. Poultry, be it remembered, forms a considerable percentage of the ordinary meat diet, particularly of invalids and convalescents, and beyond doubt tuberculosis can be contracted through the medium of the alimentary canal. We have, therefore, made a series of experiments with a view of checking these statements.

1. Two fowls, *a* and *b*, were *fed* with purulent material, taken from a *human* tubercular lung, which contained abundance of tubercle bacilli :

Both were killed 62 days afterwards. Fowl *a* was very emaciated. In its liver were found numerous tubercular deposits, yellowish in colour, varying in diameter from $\frac{1}{5}$ to $\frac{1}{4}$ of an inch. The lymphatic glands in the omentum were much enlarged and caseous. The spleen and intestines appeared normal.

Fowl *b* was found to be exceedingly well nourished. In its liver were present several whitish spots. All other organs appeared healthy. The deposits in the liver of this as well as of the other fowl contained the tubercle bacilli.

2. Two fowls, *c* and *d*, were *fed* with purulent material taken from the tubercular lung of a *cow*. Each animal received altogether about one pound by weight of this tubercular material, which teemed with tubercle bacilli :

Both fowls were killed 68 days afterwards and were found extremely well nourished and fat; no trace of disease was anywhere to be seen in them. For "control" two guinea-pigs had been fed with same bovine material; they died after 36 and 84 days from well-pronounced general tuberculosis.

3. Two fowls, *e* and *f*, were *inoculated* subcutaneously with purulent material of a *human* tubercular lung:

Fowl *e* was killed 149 days after; it was found well nourished and fat, all organs healthy.

Fowl *f* was also killed after 149 days. Small tubercular deposits, few in number, were found in the intestine, liver, spleen, and abdominal lymphatic glands.

4. Two fowls, *g* and *h*, were *inoculated* subcutaneously with purulent matter of the tubercular lung of a *cow*:

Fowl *g* died 71 days after inoculation, very much emaciated, but no sign of tubercular disease in any organ.

Fowl *h* was killed 154 days after inoculation. It was found very fat and well nourished; no sign of any disease in any organ.

Three guinea-pigs were inoculated for control with the same bovine tubercular material. They died after 52, 54, and 58 days respectively from well-pronounced tuberculosis.

It follows from these experiments that while fowls are susceptible to tuberculosis as the result of feeding and of subcutaneous inoculation with human tubercular matter, they appear insusceptible to bovine tubercular matter introduced into their system in whatever way. This is in a high degree confirmatory of a view expressed in former reports (1883 and 1884), viz., that the two diseases, bovine and human tuberculosis, are not identical. Former experiments it will be remembered had shown different behaviour of guinea-pigs and rabbits towards the two diseases.

As regards the infection of fowls with human tubercular matter, it is important to note that some of these fowls were found on post-mortem extremely fat and well nourished, notwithstanding the presence in their internal organs of tubercular deposits. This circumstance is the more important since, for market purposes, such animals would be considered "very fine."

5. As a kind of "control" to the above, the following experiment was made:—

A fowl in a miserable condition was brought to the Brown Institution for the purpose of being killed. On post-mortem examination the liver was found greatly enlarged owing to presence in it of numerous tubercular deposits; the mesenteric glands and the intestine also contained tubercular deposits. In all these tubercular deposits, viz., of the liver, the mesenteric glands, and the intestine, tubercle bacilli were found in abundance.

The liver was mashed up in neutral salt solution, and with it two guinea-pigs, *i* and *k*, were *fed*:

Guinea-pig *i* died 193 days afterwards. Its body was well nourished. The large intestine contained in its wall numerous tubercular deposits, some a $\frac{1}{4}$-inch in diameter. Some of the mesenteric glands were enlarged and caseous; there was also peritonitis. The lungs, liver, kidneys, and spleen appeared normal.

Guinea-pig *k* was killed 219 days afterwards. It was very fat and well nourished. Lungs, liver, and kidneys appeared normal. One bronchial gland enlarged. Spleen contained five large tubercular deposits. In both guinea-pigs certain of the tubercular deposits contained tubercle bacilli. Intestines appeared normal; mesenteric glands enlarged.

Former observations (see Report, 1884, pp. 169 and 170) have shown that guinea-pigs fed with bovine tubercular matter develop tuberculosis more quickly and with wider implication of the viscera than guinea-pigs fed with human tubercle. From the above experiments, therefore, it would appear that as regards guinea-pigs the infectivity of tubercular matter derived from the fowl corresponds more nearly with that of human than that of bovine tubercle. And this fact of the exceedingly weak effect produced by tubercle from this fowl in guinea-pigs, *i* and *k*; viz., that after 193–219 days there was, comparatively speaking, very little disease found in the viscera; appears to have a significance of its own. It suggests that the body of a fowl, though susceptible to infection with human tubercular matter, is by no means a soil in which this matter acquires increase of its virulence; but that on the contrary it is a soil in which tubercle loses much of its infective power. If this be really the case, there would appear to be possibility that by the passage through the fowl of human tubercular virus, attenuation of this virus might be effected to an extent permitting of use of it for protective inoculation. Further experiments are, of course, required for elucidation of these points.

No. 3.

Preliminary Report on the Mode of Action of Pathogenic Organisms; by L. C. Wooldridge, M.B., D.Sc., M.R.C.P.

There can be scarcely any doubt that the ultimate action of pathogenic organisms in producing disease is a chemical one; and, although suggestions and theories have not been wanting as to the nature of this action, the subject is still involved in very great obscurity.

Organism used.

Dr. Klein has placed at my disposal, for the purposes of research, a bacillus, which produces a rapidly fatal form of septicæmia in guinea-pigs and rabbits. Dr. Klein has himself studied and described the morphological and physiological characters of this organism (*see* Appendix B, No. 4, page 178, and plate facing page 184), so that it will only be necessary for me to give an account of the observations I have been able to make as to the mode in which this organism produces its fatal effects. It must be added that, owing to the short time I have been engaged on this subject, these observations are still very incomplete.

It has recently been shown* that, under the influence of certain non-pathogenic organisms, poisonous substances of the nature of alkaloids are produced in organic media; and it has been assumed that such poisons may arise in the animal body, as the result of the activity of pathogenic organisms, thus accounting for the toxic influences of the latter. But satisfactory proof that pathogenic organisms are capable of producing such poisons, does not at present exist; and as this is a very important subject, attention was particularly directed to this point in the case of the septicæmic bacillus now under consideration.

For an inquiry of this nature, there are objections to the use of the more complex media more generally employed for purposes of culture, such as peptone broth, or peptone and sugar; and in the case of this particular organism it was found more suitable to make use of a vegetable albumin. Vegetable albumins are obtainable commercially from various sources, and the one used in these experiments has been obtained from the Brazil nut.

Method of culture.

The raw product is extracted with dilute alkali, filtered, and the clear solution precipitated by neutralization with acetic acid. The solid matter is collected by means of the centrifugal machine, and washed. It is again dissolved in dilute alkali, and this solution forms the cultivating medium for the septic bacillus under consideration. With regard to this solution, it is to be observed that it may be injected in large

* Brieger; über Ptomaine.

quantity into the circulation of the rabbit without producing any obvious disturbance.

Before inoculating the bacillus into the solution of vegetable albumin, the solution is thoroughly sterilized by prolonged boiling on several successive days. Provided sufficient alkali be present, the only change the albumin solution undergoes on boiling is that it becomes very slightly opalescent. It will be necessary hereafter to ascertain the exact amount of proteid and of alkali which the solution should contain; here it may be said that it is of great importance to avoid any excess of alkali, as this exerts an unfavourable influence on the growth of the bacillus.

Influence of Organism on proteid solutions.

When the solution of vegetable albumin has been fully sterilized, it is inoculated from a pure culture of the bacillus on peptonised gelatine broth, and the flask containing the albumin solution is kept in the incubator at a temperature of 36°–37 C. After a short period, varying from two to four days, a voluminous precipitate occurs in the fluid. The time which elapses between inoculation of the solution and the appearance of the precipitate depends on conditions not yet understood, among them the degree of alkalinity of the fluid probably being the most important.

When the precipitate has appeared, a small quantity of the contents of the flask is drawn off by means of a sterilized pipette, and from this gelatine tubes are inoculated, so that a control as to the purity of the culture may be obtained. The general characters of cultivations on gelatine are given in Dr. Klein's paper.

Microscopically examined, the precipitate is found to contain large numbers of bacilli, but at the same time it is found on careful examination that these bacilli do not make up the bulk of the precipitate. That consists principally of a very finely-granular substance, which chemical examination shows chiefly to be proteid matter. Indeed, when the precipitate has fully developed, the supernatant fluid is found to contain only a very small quantity of proteid.

The culture fluid is still markedly alkaline, when the precipitate is fully developed. Hence the precipitate cannot be referred to the production of an acid body by the bacillus. The growth, then, of the bacillus has caused the precipitation of the bulk of the albuminous matter contained in the original solution. This matter can hardly be regarded as representing the débris of organisms. For in the first place, the rapidity with which the precipitate is formed renders this almost impossible. and secondly, the bulk of the growth and of the débris of growth which is formed in other fluid media (for instance, peptone broth), is very much smaller than the precipitate under consideration.

Precipitate produced by organisms.

The precipitate caused by the operation of the bacillus can be readily collected and washed by means of the centrifuge. When so collected it is found to be much less readily soluble in dilute alkali than was a precipitate formed by acetic acid from the original solution of vegetable albumin.

The bacillary precipitate having been treated with dilute alkali is filtered through a fine linen cloth, and in this way a fluid is obtained, turbid, but free from any visible solid particles. This fluid possesses very marked toxic properties, for, if injected into the circulation of a rabbit, it will cause death in less than a minute.

To produce this result, however, a considerable quantity of the fluid must be injected, or more exactly stated, the fluid injected must contain

a considerable quantity of the precipitate in suspension. I estimate the quantity necessary to kill a rabbit as 0·5 grm., but it must be understood that this is only an approximation. A less quantity produces no very obvious immediate effects; but as the animal is under the influence of an anæsthetic when the injection takes place, milder symptoms may be masked. The animal is killed before the anæsthesia is over.

The precipitate alone poisonous.

The fluid which was separated from the precipitate, that is to say, the original culture fluid after the removal of the precipitate, does not exert any immediate toxic effect when injected in large quantity into the blood.*

No doubt the precipitate caused by the growth of the bacilli contains, after being taken up by the dilute alkali, a great number of the bacilli in suspension. But then, in like manner, there are a large number of bacilli to be found in that solution of the proteid which had shortly before been inoculated with them, and in which the precipitate has not yet made its appearance: yet the injection of this solution is not followed by any immediate toxic effect; so that the rapid toxic effect cannot be referred to the bacilli themselves.

The actual cause of the rapid death, above referred to, appears to be respiratory paralysis, the heart continuing to beat for some time after the respiration has stopped. In one or two instances I have observed intravascular clotting, but this is not constant. In four cases, however, a marked acceleration of the clotting of the blood after it left the vessels, was noticed.

Probably a proteid poison.

These changes in the blood are of interest because it has been shown† that a very poisonous substance can be obtained from many animal tissues. This substance is a complex proteid body, and it presents some analogies in its mode of action with the precipitate produced by our septicæmic bacilli. As has been stated, the latter consists chiefly of proteid matter; whether it is this which has the toxic power, or whether this power is due to some other substance contained in the precipitate, must be left an open question till further experiments can be made.

One conclusion may be safely drawn from these observations, viz., that the growth of this bacillus in vegetable albumin solution does not result in the production of any soluble poisons, since only the precipitate has any toxic action,—the fluid is inert. If it can be definitely shown that growth of bacilli in solutions of innocuous proteids can rapidly convert these into noxious bodies, a great advance in our knowledge of the action of pathogenic organisms may be possible, and perhaps these observations may be taken as an indication in this direction. They are certainly not favourable to the ptomaine theory.

Virulence varies with medium.

In addition to the observations already described, one other point of interest was brought out. It was found that the organisms could be cultivated in the following fluid:

Kreatin, 1 grm.
Glucose, 0·5 grm.
Potassium phosphate, 0·5 grm.
Lime and magnesia—traces.
$\frac{1}{2}$% Solution of common salt, 100 c.c.

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* "Immediate," because the animal is killed before the expiration of the anæsthesia.

† Wooldridge, Proc. Roy. Soc., Feb. 4th, 1886.

The growth produced was always of very limited extent, but the toxic influence of the organisms was preserved through many successive generations. But although the organism still retains its activity when inoculated, it is very much less virulent than when grown in peptone broth or other albuminous fluid. Inoculations from a growth of peptone broth cause death in guinea-pigs in from two to four days. Whereas, the average time elapsing between inoculation and death in the case of the growth in the kreatin solution was seven days.

No. 4.

On the Action of Perchloride of Mercury on Bacteria; by E. Klein, M.D., F.R.S.

On the Action of Perchloride of Mercury on Bacteria; by Dr. Klein.

From the researches of Koch it is known that mercuric bichloride has a powerful action on bacteria. Koch found (Ueber Desinfection, Mittheil. aus d. k. Gesundheitsamte, Berlin, I., 1881, p. 264) that a solution containing sublimate in the proportion of not more than 1 in 5000 kills the spores of bacillus anthracis, *i.e.*, the spores become hereby incapacitated from afterwards growing in suitable media, and incapable also of producing anthrax when inoculated into animals. Koch further found (*l.c.*, p. 269) that if to blood serum or to meat extract peptone solution sublimate is added in the proportion of 1 to 1 million, and spores of anthrax are sown in the mixture, there is a marked restraining power effected on germination of the spores and on growth from them of bacillus anthracis. If sublimate be added to the above solutions in the proportion of one to three hundred thousand no germination and no growth of any kind takes place of spores sown therein. As will be seen, I have however convinced myself by numerous experiments that these figures do not express the actual facts.

Earlier observations.

On anthrax spores and bacilli.

As regards the amount of exposure necessary for exercise of the killing power of sublimate on spores of anthrax, Koch states (*l.c.*, p. 276) that the spores of anthrax are completely disinfected by 1 per mille solutions of sublimate even if acted upon only for ten minutes. And that even after simple but complete moistening of the spores (by means of a spray producer) with a 1 per mille solution, or even with a solution of 1 in 5000 of sublimate, the spores are killed. The correctness of these results I question also: my observations indicate no such killing power, as I shall proceed to show. In reference to the time necessary for exercise of the killing power of one and another strength of sublimate solution on spores of anthrax, Koch found (*l.c.*, p. 276) that solutions of 1 in 20000 acting for 10 minutes kill the spores, for these when transferred to nutritive gelatine were incapable of germinating; whereas 1 in 50000 even after 60 minutes exposure of the spores to it, had no appreciable effect, since spores thus treated grew on nutritive gelatine as luxuriantly as unmedicated spores. But these results as to the behaviour of medicated spores after transference to nutritive media are no certain test of the killing power of the perchloride, as is indeed incidentally shown by Koch himself in certain inoculation experiments with such spores on mice. In the experiments of Koch here referred to, spores of anthrax, having been acted upon for ten minutes by sublimate of the strength of 1 in 10000, were injected into a mouse, with the result that the animal died of anthrax. Similarly, death occurred in a mouse which had been inoculated with spores that had been acted upon also for 10 minutes by sublimate 1 in 20000. It is true these mice of Koch's did not die as rapidly as normally; the first mouse died, for instance, on the fifth day and the second mouse on the fourth day; but they did die of anthrax, and therefore Koch is not justified in saying that sublimate of the strength of 1 in 20000 kills the spores of anthrax after 10 minutes' exposure to it. Koch also states (p. 577) that even the most resistant of spores, as for instance those of the bacilli of garden earth, are killed by sublimate 1 per mille after a moistening lasting only a few minutes; and he concludes from this that mere moistening with sublimate of this strength, viz., 1 per mille, is absolutely fatal to all, even to the most resisting, bacteria. My experiments, to be detailed

Duration of exposure.

Qualifications.

below, make me dissent from this general statement of Koch; they prove that the killing power of sublimate is, as regards some spores, much less uniform than recorded by Koch; that it differs considerably not only as regards different bacteria, but also as regards the same species in different phases of its development (*e.g.*, the spores as contrasted with the bacilli of anthrax); and that these differences of killing power depend to a considerable degree on the soil in which the spores or the bacilli have been growing.

Influence of nutritive media.

As to the restraining power of sublimate solutions, Koch records (*l.c.*, p. 279) in regard of a series of experiments made with meat extract peptone solution, that the spores of anthrax were distinctly inhibited in their growth if the amount of sublimate added to the nutritive fluid was 1 in 600000; if the amount was 1 in 330000 no development at all took place. But Koch expressly guards himself by stating (*l.c.*, p. 267) that no absolute value can be attributed to these figures of his, since the constituents of the nutritive medium (*e.g.*, proteids, salts, &c.) may themselves influence the action of a disinfectant added to them. Mr. Laws, too, has pointed out in these Reports (1884) that the presence of peptone in a disinfectant solution (phenylpropionic acid) has a similar modifying influence. I shall return to this point later on.

Of specific differences.

Sternberg in the Report of the Committee on Disinfectants of the American Public Health Association, 1885, describes (pp. 51–61) a series of experiments made with mercuric chloride. He says (p. 51) "my own observations are in accord with those of Koch and others, as "to the power of this agent in dilute solutions (1 : 1000 to 1 : 10000) "to destroy the spores of bacilli, B. anthracis and B. subtilis, and these "constitute the most severe biological test known. Micrococci and "bacilli in active growth without spores, are killed by much weaker "solutions (1 : 20000 to 1 : 40000) than are spores."

On p. 54 Sternberg states that mercuric chloride was added to a sterilized culture fluid in the proportion of 1 : 100000, 1 : 200000, and 1 : 400000, before addition to the culture fluid of spores of bacillus anthracis. At the end of 48 hours there were present flocculi of anthrax filaments in the last sample (1 : 400000), but the other samples remained clear. Sternberg goes on to say that the restraining power of mercuric chloride is not so great for the spores of bacillus subtilis as for those of anthrax.

Sternberg's statement that his results coincide with those of Koch is not borne out by the experiments he himself records on p. 56. For we there see that while in one experiment exposure of spores of anthrax to mercuric chloride 1 : 10000 for one hour succeeded in killing the spores, in another experiment the same process left the spores quite uninjured.

Sternberg's observations seem to me to be too few and too fragmentary to warrant any such general conclusions as he draws from them, and I propose showing how and in what manner a variety of conditions, other than the disinfectant agent, are likely to have influenced to a considerable degree the results he obtained.

Actions of mercury: killing and *restraining.*

The experiments which I now propose describing were made with a view of studying systematically the value of perchloride of mercury, in reference to its power to disinfect, *or kill*, various bacteria, septic as well as infective or pathogenic; and with a view also of ascertaining its ability to hinder, *or restrain*, bacteria from growing in suitable nutritive media, to which perchloride of mercury in certain proportions had previously been added.

But in order to have an absolute index of the killing power of any disinfectant, it is obviously necessary to experiment with the disinfectant

in its pure state, *i.e.*, in a solution in distilled water. The testing of a disinfectant in solutions containing proteids, salts, and other substances, although capable of affording, perhaps, valuable information, does not give us any correct idea of the absolute power of the disinfectant, since the disinfectant may have entered into combinations with the proteids, salts, or other substances, whereby its action on given infective material may have been seriously interfered with. In this connexion I would refer to my own and Mr. Laws' reports for 1884, and to the observations of Koch. I have shown, in my report for 1884, that the action of phenylpropionic acid is much more powerful than that of its sodic salt; similarly Mr. Laws has shown that the acid itself has in peptone solutions a greatly inferior power than when used in watery solution; and Koch has shown in regard to carbolic acid that in watery solutions its action is more powerful than in proteid solutions, or than in the form of carbolic oil. Obviously therefore perchloride of mercury, which has a great affinity for proteids, might be expected to lose a good deal of its action when changed in their presence into an albuminate.

Procedures adopted.

For the above reasons I have in my experiments as to *killing power* used the perchloride of mercury in solution of distilled water. To such solutions of different strengths various bacteria were added and kept therein for a variable length of time; afterwards, the vitality of the organism was tested in the usual fashion.

The *modus operandi* was always this:—

Of a bacterial fluid a droplet was drawn up, or allowed to ascend by capillarity, into the tube of a freshly drawn-out glass pipette such as I generally use for transferring or inoculating bacteria from and into fluid media. Then into this same pipette the mercurial solution to be tested was drawn up in such amount that the mixture in the pipette contained the original bacterial droplet diluted about 100 times by the mercurial solution. [It is not difficult to get these proportions always about the same, if by practice one has learned to make capillary pipettes of a uniform thickness of glass tubing; and it is possible to make them of a size which in the different pipettes shows variations not greater than one or two drops. By practice it is likewise possible to take up always the same amount of bacterial fluid for mixture with the perchloride solution. In my actual experiments the proportion of bacterial fluid to mercuric solution was never less than 1 in 100.] After leaving the bacterium and the disinfectant thus in apposition for a given time, samples of the mixture were used for inoculation of culture tubes containing solid nutritive gelatine or fluid media (generally sterile faintly alkaline broth peptone (1 p.c.)), or meat extract peptone (1 p.c.) solution. These tubes were then placed in the incubator, and the growth occurring in them (if any), its character, and its differences from those of the normal organism, noted.

[For inoculation of a culture tube a drop of the mixture was used; the nutritive medium in each test tube amounted to between 6 and 10 CC. By microscopic examination it was ascertained that a sample drop of the mixture contained the organisms few and far between, *i.e.*, well separated in the diluting mercurial solution.]

In all instances bacteria only were used, the characters of which have become well known. All were used in a pure state, and in regard of septic and pathogenic organisms investigated control experiments were always made.

As regards septic organisms: before mixing them in the manner already described with the mercuric solution, inoculations of control tubes (nutritive gelatine, broth peptone, &c.) were made; then after exposure of the organism to the disinfectant for the required time,

samples of the mixture were put into test tubes containing nutritive material of similar sort. Both sets of tubes were next subjected to the identical conditions of temperature—(in the case of solid gelatine 19–20° C., in the case of fluid media 35–37° C.),— and any differences subsequently occurring in the two sets of tubes were noted.

As to pathogenic organisms: a double set of control experiments was instituted, viz., control by cultivation in artificial nutritive media, and control by inoculation into animals. For instance, samples of the organism about to be exposed to the action of the mercuric solution were first tested by inoculation into culture tubes and as well by inoculation into animals. Then samples of the mixture of organisms and mercuric solution were inoculated into other but similar culture tubes, and as well into other but similar animals.

Be it then understood that all the statements which will be given below as to the action of mercuric solutions on bacteria imply that in every single instance control experiments had been made in the manner above described.

Water-influence set aside.

Before actually commencing my disinfection experiments I made sure that distilled water had *by itself* no injurious effect on the organisms about to be employed when mingled with them in amount similar to that to be used in regard of the mercuric solution. For, unless this were done, it might be said—and as a matter of fact it has been said—that by using an antiseptic in watery solution we might get a double action on the organisms submitted to it, viz., that of the water and that of the antiseptic. Now, I do not for a moment question that an organism which does not form permanent seeds, *e.g.*, micrococcus, will die, if after growing in a nutritive solution it be transferred to, and kept for an indefinitely long time in, a large amount of water; for in water there is practically no amount of nutritive matter, and consequently no material by consumption of which the organism can sustain its life. That this is true, Koch has shown in the case of the commabacillus; but to me it is beside the real question. The point we are examining is this: given a bacterial fluid diluted to 50 or 150 times its amount with distilled water,—do the contained bacteria suffer hereby any immediate deleterious effect? This question I can, from a large number of experiments, answer with absolute certainty. They do not. Heart's blood, for instance, of an animal recently dead from virulent anthrax and full of bacilli anthracis was diluted with tap water and with distilled water until the proportions were 1 part of blood to between 50 and 200 parts of water. Different samples, after being kept for half an hour, for one hour, and for 24 hours, were used for the inoculation of guinea-pigs and of test tubes. In the result the action of the water on the bacilli proved nil; for the cultures produced in the usual time growth as luxuriant as that of normal bacilli, and the inoculated animals died in the ordinary fashion from typical anthrax. Similar experiments were made with septic organisms, and the result was the same.

Having thus ascertained that a dilution of the bacterial fluids which I was using—with distilled water 1 to 100 or more, and kept mixed therewith for 48 hours—has no adverse effect whatever on the bacteria, I proceeded with my experiments on the action of perchloride of mercury dissolved in distilled water.

The organisms experimented with were the following:—

Experiments on several forms of bacteria.

1. *Bacillus subtilis.*—This organism corresponded, as regards its size, its motility, its power to grow into threads, to form a pellicle on the surface of fluids, and its ability to form spores, to the bacillus of hay

infusion, the hay bacillus of Cohn. The bacillus which I experimented with was obtained from a Jequirity infusion, and the organism was grown in broth peptone on nutritive gelatine, and on Agar-Agar mixture. Broth peptone, exposed to 35° C., becomes uniformly turbid 24–48 hours after inoculation with the bacillus. After another day or two a pellicle is gradually formed on the surface, which, as development proceeds, thickens and becomes more coherent. In this pellicle, which is composed of bacilli matted together, active spore formation is going on. In about a week the broth becomes again more or less clear, a thick whitish precipitate having settled at the bottom of the culture tube; the surface meanwhile remains covered with a thick white pellicle. On shaking the tube containing it this pellicle easily breaks up into separate masses, which fall to the bottom of the tube. On nutritive gelatine, kept at 19–20° C., this bacillus grows very copiously, and as the growth proceeds the gelatine becomes liquefied, a white pellicle of bacilli being formed at the surface. After some weeks the whole of the gelatine becomes liquefied; it is clear, and a thick whitish precipitate occurs at the bottom of the tube, and on the surface of the liquid a pellicle is formed. On Agar-Agar meat extract peptone mixture, kept at 35° C., the bacillus grows very rapidly, and in two or three days has spread over the whole surface as a whitish-grey smeary thick pellicle, copious spore formation taking place in the bacilli.

2. *Commabacillus of Finkler.*—The morphological characters of this organism and its behaviour in cultivations need not here be described, since they are well known from the descriptions given by Koch and his pupils and by Finkler and Prior.

3. *Commabacillus of Koch.*—This, as it occurs in cholera asiatica, is from Koch's writings, also sufficiently well known as to its morphological and culture characters.

4. *Micrococcus prodigiosus.*—The organism used in my experiments is, as regards size, its bright pink colour when growing in masses, and its power to liquefy gelatine, the same as that universally known from the researches of Schrötter (Zeitschrift d. Biolog. d. Pfl.).

5. *A micrococcus isolated from the contents of the ileum of monkey.*—This micrococcus is of a larger size than micrococci usually are; it is spherical, its diameter 0·001 to 0·002 m.m. It occurs as dumb-bells and smaller or larger zoogloœa masses. It grows copiously in broth peptone, forming, after several days' growth at 35° C., a voluminous grey precipitate at the bottom of the fluid; on the surface there is a thin grey pellicle showing very little cohesion. The culture fluid does not become clear, but remains turbid. On nutritive gelatine it grows also copiously; it liquefies the gelatine slowly, but though liquefied the gelatine does not become thin and watery as it does when acted on by many liquefying bacilli (bacillus subtilis, Koch's and Finkler's comma-bacillus, bacillus anthracis, &c.); on the contrary, it becomes like thick syrup and remains uniformly turbid. On the surface of the liquefied gelatine there is formed, as on the surface of peptone broth, a thin greyish pellicle showing very little cohesion. When inoculated into the substance of nutritive gelatine by means of a platinum wire or the end of a capillary glass pipette,—the charged instrument being pushed into the gelatine,—there appears in the gelatine, after two to three days' incubation at 19–20° C., a greyish streak indicating the channel of inoculation. After another day or two there is on the free surface of the gelatine a well-defined funnel-shaped drawing in or sinking down, with subsequent occlusion of the orifice of the pit thus formed by an air-bubble, such as is mentioned by Koch and his pupils as characteristic of choleraic commabacilli. On Agar-Agar mixture it forms a greyish

thick film, spreading from the point of inoculation with a more or less irregular outline.

6. *Bacillus anthracis.*—This needs no description, having been fully dealt with by me in previous reports.

7. *Bacillus causing a form of septicæmia in guinea-pigs.*—The morphological and physiological characters of this organism will be described in detail later on.

8-9. *Various streptococci* and *bacillus tubercle.*—A few experiments on these will be recorded.

Before proceeding to inquire in detail respecting the effect of perchloride of mercury on each of the several micro-organisms enumerated, I made some preliminary investigation of it in very strong solution on all of them. And I found that a solution of 1 part of the salt in 100 distilled water was fatal to all alike, that were exposed to it for some minutes, whatever the phase of their development; but that a more dilute solution then 1 in 100, though it killed, in like time with the first, all the organisms that were in growing phases, *failed to kill the spores* of bacillus subtilis and bacillus anthracis.

Experiments with Bacillus Subtilis.

On Bacillus subtilis.

From a recent cultivation of the bacillus subtilis in broth peptone in which for some days active spore formation had been going on, a trace of the spore material was withdrawn with a capillary pipette and diluted at least 100 times with a 1 per mille solution of sublimate. The mixture thus made was kept for one hour, at the expiration of which time several tubes of sterile broth peptone were inoculated with it. After 24 hours' incubation at 35° C., there was copious growth of bacillus subtilis, the progress and the character of the growth being quite normal. The same experiment was repeated with the same spores, and with the same result, *i.e.*, 24 hours after there was good growth of the bacilli.

Killing power of mercury

Now, Koch found in his experiments that the spores of the bacilli of garden earth merely moistened well with a 1 per mille solution of sublimate were killed, while Sternberg (*l.c.*, p. 57) found that a solution of sublimate 1 : 10000 acting for one hour was required for killing the spores of bacillus subtilis; 30 minutes was, he noted, insufficient. The difference in the results obtained by Koch, Sternberg, and myself, with one and the same species is sufficiently striking, and it would appear not easy of explanation. But, as will be seen later on, I have ascertained by a series of experiments (1) that it is perfectly unjustifiable to draw general conclusions from experiments of this nature on a *single species* and apply them without discrimination to other similar organisms of the same genus; and (2) that working with one definite species only, but growing it in different media and for various periods of time the results differ greatly according to the nutritive medium in which the particular organism has been grown, and according to the time during which it has been growing therein.

The observations, therefore, of Koch as regards the behaviour of the spores of bacilli of garden earth towards sublimate solution 1 : 1000, can be held to have reference to those spores *and those only* with which he was working. Whether the spores of this bacillus when grown in different media and for different lengths of time behave always in the same manner had not been ascertained, no comparisons having been made; and it is not therefore open to anyone to extend the conclusions derived by Koch from his observation of the action of sublimate on the

spores of the bacilli of garden earth, to the spores of other bacilli. A like criticism may be applied to Sternberg's observations.

In proof of the fact that the same species behaves differently when grown in different media, I record the following observation :—Spores of the bacillus subtilis were inoculated some into tubes containing faintly alkaline broth* peptone (1 p.c.), others into faintly alkaline nutritive gelatine (*i.e.*, broth containing 10 p.c. gelatine, 1 p.c. peptone). After about a week, spores that had developed in the resulting subcultures were subjected separately to the action of the sublimate solution (1 : 1000). The spores derived from the subculture in broth that had been acted upon by the sublimate solution for one hour, showed absolutely no alteration in the nature and amount of the growth developing from them when transferred afresh to sterile broth peptone ; but spores that had developed in the gelatine tube behaved differently. Spores from this gelatine tube were also mixed with the sublimate solution (1 : 1000), and after remaining only 30 minutes in the solution were transferred into sterile broth peptone ; and at the same time, as a control experiment, spores from the same gelatine tube but which had not been subjected to the sublimate, were inoculated into sterile broth peptone of the same stock. As a result, the growth appearing in the latter tubes, after exposure to 35° C., presented normal appearance, viz. :—uniform turbidity, numerous motile bacilli, good formation of thick pellicle with abundant spores,—whereas the growth in the former tubes was distinctly less in amount; and it occurred only at the bottom of the fluid in the shape of a fluffy whitish mass, which on microscopic examination proved to consist of convolutions of bacillary threads; the fluid, however, contained no motile rods, no spores, and no pellicle was formed on the surface ; the supernatant fluid, moreover, remained clear. From this modified growth I inoculated several other test tubes of broth peptone ; in all of them the growth took effect and the products were typical in amount and appearance, the fluid becoming uniformly turbid and containing numerous motile bacilli ; a thick pellicle, moreover, was formed and copious spore formation took place.

observed on the spores ;

There can be no question as to this having been the same bacillus subtilis with which the experiment began. Nevertheless spores from a growth of it in gelatine after having been exposed for 30 minutes to the sublimate solution produced a growth having for a single generation slightly altered characters, though it displayed normal characters in the next succeeding subculture. No such effect, however, was produced on spores from a growth of it in broth peptone exposed for one hour to the action of the same strength of solution of the sublimate ; for these latter germinated and grew in the usual fashion. There can be no doubt, then, about this fact, viz., that spores derived from a single sample of a given species, but grown in different media have a different resisting power to the sublimate solution ; those grown in broth peptone being more resisting than those grown in gelatine.

on sporeless bacillus subtilis.

Bacillus subtilis, at a stage of growth before spores made their appearance, was also tested in its power to resist the action of perchloride of mercury.

[In order to obtain these bacilli in sporeless form, I used test tubes containing broth peptone inoculated with the bacillus subtilis (spores or sporeless) 24–36 hours previously. If such tubes are kept at rest in the incubator at 35° C., the culture, although swarming with the bacilli, many of them motile, does not up to 36 hours afford any bacilli containing spores ; after 36 hours I should not rely on there being no spores

* Broth in this and all other instances means beef broth.

present.] Sporeless bacilli thus grown in broth peptone, and afterwards subjected for 30 minutes to the action of a solution of perchloride of mercury of the strength of from 1 : 10000 to 1 : 15000 inclusive, were invariably killed, for no growth could be started with them. But if there were spores present the result, as I have already said, was altogether different.

If the solution of sublimate is, however, weaker, viz., 1 : 20000, the time of exposure being still 30 minutes, we find after 24 hours in all tubes inoculated, commencing growth; after two days this growth is normal both in amount and aspect in one half of the tubes, but retarded in amount in the remaining tubes. I conclude from this that some of these sporeless bacilli are liable to be affected by the sublimate in this strength, though they are not killed. If, however, the bacilli on which the above mercuric solution had been acting for 30 minutes be examined under the microscope, it is seen that all their motility has been lost. Solutions weaker than the above, as, for instance, 1 : 25000, had no effect on the bacilli.

Restraining influence of mercury.

The next point investigated was the *restraining power* of perchloride of mercury on the above bacillus subtilis.

In this, as in all other cases, wherein *restraining power* was tested, nutritive gelatine or broth was used. To a definite volume of this a definite quantity of a watery solution of sublimate was added, so that the mixture always contained the sublimate in a definite proportion to the total fluid; *e.g.*, if to 90 CC. of nutritive gelatine or broth 10 CC. of a 1 p.c. watery solution of sublimate is added, the mixture will contain 1 part sublimate in 1000; if to 90 CC. of nutritive material 10 CC. of a 1 per mille watery solution of sublimate is added, then the mixture contains 1 part sublimate in 10000, and so on.

The mixture of cultivating medium and disinfectant was contained in sterile test tubes; the organism of a recent culture in broth peptone was then introduced, and the gelatine or broth tubes thus inoculated were kept in the incubator at 19—20° C., and at 35—70° C. respectively. It was found that if the quantity of the sublimate added to the gelatine or broth amounted to 1 : 20000, a growth of the bacilli occurred, no matter whether only *spores* or only *sporeless* bacilli were used for inoculation; and that such growth took place in the normal time, as was proved by inoculating simultaneously bacilli from the same original source into unmedicated nutritive gelatine or broth tubes.

If the amount of sublimate added to the gelatine was 1 : 10000 no growth of any kind took place.

These results differ considerably from those obtained by Koch with the spores of the bacillus anthracis, since in his experiments (*l.c.*, p. 279) the spores did not germinate at all if the amount of sublimate added to the nutritive medium was 1 : 300000; and even 1 : 600000 had, he says, a decidedly restraining power. Sternberg says (*l.c.*, p. 54) that "the "restraining power of sublimate is not so great for the spores of bacillus "subtilis as for those of anthrax;" for he found that in two flasks containing in the nutritive medium sublimate in the proportion of 1 : 50000 there was a good growth of bacillus subtilis with pellicle formed after 48 hours. In my experiments sublimate 1 : 20000 had no restraining power whatever on the spores and bacilli of the above bacillus subtilis.

Experiments with Finkler's Commabacillus.

On Finkler's Commabacillus Killing power.

(*a.*) The commabacilli, taken from a recent (one week old) culture in nutrient gelatine, were mixed with a solution of sublimate 1 : 10000 and

1 : 15000. After 30 minutes, tubes containing (faintly alkaline) broth peptone were inoculated with this mixture, but no growth of any kind made its appearance. Then in a similar way sublimate 1 : 20000 was tested; time of exposure also 30 minutes. Inoculations of the broth peptone with this mixture yielded a retarded, very scanty growth.

As is well known, both Finkler's and Koch's commabacilli are actively moving organisms. But when Finkler's and Koch's commabacilli are subjected to sublimate solution 1 : 20000 for 30 minutes all movement of the organisms ceases.

Finkler's commabacilli, after having been subjected to a solution of 1 : 25000 for 30 minutes, yielded in broth peptone a good growth of the organism.

From this it follows that the killing power of sublimate on Finkler's commabacillus is the same as on the sporeless bacillus subtilis.

Restraining power.

As regards the restraining power of the perchloride on Finkler's bacillus: To test this, broth as well as nutrient gelatine was used. After adding to these materials solution of sublimate in such proportions that different samples of the mixture contained 1 sublimate in 1000, 1 in 10000, 1 in 20000, and 1 in 25000, the several samples were inoculated from a culture of the commabacillus in normal nutrient gelatine about a week old.

The result was this:—The tubes containing sublimate 1 : 1000 showed no growth of any kind even after many days; the tubes containing sublimate 1 : 10000 showed a retarded growth, which after several days was of fair amount, but not quite as good as in normal tubes; those containing sublimate 1 : 20000 showed growth which in point of time, amount, and character showed very little difference from the normal; while those containing sublimate 1 in 25000 could not be distinguished from normal tubes. The restraining power of sublimate on Finkler's commabacillus is then about the same as on the sporeless bacillus subtilis.

Experiments with Koch's Commabacillus.

On Koch's Commabacillus

The experiments were precisely similar to those with Finkler's commabacillus, and the results both as to the killing and restraining power of sublimate were almost identical. There was only this slight difference between the two, namely, that in some—not in all—experiments, Finkler's commabacillus showed a resisting power to sublimate a shade greater than that of Koch's. Thus, for instance, I find in my note book in one series of experiments made on August 3rd, "inoculated both commabacilli at the same time severally into gelatine tubes containing sublimate 1 : 10000, 1 : 20000, and 1 : 25000; normal gelatine tubes being at the same time inoculated for control. On August 8, normal growth of Finkler's commabacillus in the tube containing sublimate 1 : 20000, while in solution of similar strength inoculated with Koch's commabacillus the character of growth is the same as in the normal tubes, except that it is very slightly less in amount." In another series of experiments of a similar sort there was no difference discernible.

Experiments with Micrococcus prodigiosus.

The experiments with this organism were similar in kind to those already detailed, and the result was that sublimate was found to have a slightly greater killing power on micrococcus prodigiosus than on sporeless bacillus subtilis, and on Finkler's and Koch's commabacilli. But the restraining power was the same for all.

Experiments with Micrococcus of Fæces of Ape.

The resisting power of this organism to sublimate is considerably greater than that of those previously dealt with. Sublimate 1 : 10000 after 35 minutes' action produces no effect on it whatever; for broth peptone tubes inoculated with samples of the mixture yielded a normal growth of the organism. The same is the case with regard to the restraining power; for gelatine tubes containing sublimate 1 : 10000 when inoculated with the micrococcus, no matter whether it was obtained from normal gelatine or from broth peptone, yielded an abundant crop in the usual time.

In addition and for comparison two other series of experiments were made with two other species of micrococcus. One, a microccus, obtained from the air and characterised by its forming beautiful sarcinæ. This organism grows as white patches in nutrient gelatine without liquefying it. Nutrient gelatine inoculated from a culture of the organism by the point of a capillary glass pipette or platinum wire, shows after two or three days a white vertical streak, the channel of inoculation; during the next few days this streak thickens, and the growth at the same time spreads on the surface of the gelatine from and around the point of inoculation in the shape of a white film. The resisting power of this sarcina is much less than that of the micrococcus from the ape, and about the same as that of the micrococcus prodigiosus. The other micrococcus experimented upon was found present as accidental contamination in a gelatine tube containing a growth of Koch's commabacillus. This microccus liquefies well nutrient gelatine; it occurs as dumb-bells and small zoogloea masses, and in size it is smaller (only about half or a third the size) than the micrococcus from the fæcal matter of the ape. The micrococcus has a strikingly greater resisting power to sublimate than the commabacillus. If a mixture of the two organisms is subjected for 30 minutes to the action of a sublimate solution 1 in 10000, and broth peptone tubes are then inoculated with samples of the mixture, no commabacilli make their appearance, but after two days incubation at 35° C. the fluid teems with the micrococcus.

Experiments with Anthrax.

On Anthrax bacilli and their spores.

These comprise a very large number of observations, and include experiments with the bacillus of the blood of guinea-pigs recently dead of anthrax, with the sporeless bacillus of artificial cultivations, and with anthrax spores derived from cultivations in different media. The results are exceedingly striking, for they demonstrate in regard of *one and the same species*,—identity of the species of organisms experimented with being proved in the ability of the various samples to induce fatal anthrax in guinea-pigs,—a resistance to sublimate varying with the medium in which the organism has been growing. In addition there are some other points of special interest resulting from these experiments which will be developed as this account proceeds.

Killing power on spores.

The *killing power* of sublimate on anthrax was investigated in much detail.

In reference to *spores*, as the most resistant of all forms of anthrax, experiments were made with samples that had been developed under various conditions of culture as follows :—

(α.) Spores derived from blood bacillus grown for six months in broth were first tested by inoculation into a guinea-pig. The animal was dead of typical anthrax before the end of the second day.

Samples of the same spores then were mixed with a watery solution of perchloride of mercury—a trace of spore material being mixed in a

watchglass with a large and in each instance equal excess of sublimate solution—of the following strengths :—

1. With a solution of the strength of 1 in 120, *i.e.*, 4 grains of perchloride of mercury to the ounce of water, and kept so mixed for five minutes.
2. With a solution of the same strength for 15 minutes.
3. With a solution of the strength of 1 in 240, *i.e.*, 2 grains to the ounce, for five minutes.
4. With a solution of the same strength for 15 minutes.
5. With a solution of the strength of 1 in 480, *i.e.*, 1 grain to the ounce, for five minutes.
6. With a solution of the same strength for 15 minutes.

With a sample of each mixture, one guinea-pig (1, 2, 3, 4, 5, 6 respectively) was inoculated, care being taken, of course, to have the solutions kept separate.

The result was this: guinea-pigs 5 and 6 were found dead of typical anthrax before the end of the fifth day; their blood and spleens teemed with the bacillus anthracis, which in turn was proved to be virulent, since a sample of it killed a guinea-pig with typical anthrax before the end of the second day; blood of this animal being found full of the bacilli.

Guinea-pigs 1 and 3 were found dead on the sixth day. Their spleens were not enlarged; in the spleen of No. 1 no bacilli; in the spleen of 3 extremely few bacilli. In the blood of their hearts very few bacilli could be detected.

With heart's blood of 1 inoculated one guinea-pig.

This animal remained well.

Guinea-pigs 2 and 4 remained alive, and did not suffer any illness.

From this we see, then, that sublimate solution of the strength of 1 in 120 and 1 in 240 (samples 1 and 2), when acting for five minutes only, did not kill the spores, although it materially injured them, since the animals 1 and 3 died on the sixth day, and had moreover very few bacilli in their blood. Further, it appears that sublimate solution of the strength of 1 in 480 (samples 5 and 6) acting on the spores for 5 and 15 minutes, although it slightly injured, did not kill them, since they were capable of germination, and of producing in another experimental animal a large mass of virulent bacilli. The slight injury to the spores resulted in death of guinea-pigs 5 and 6 being delayed till the fifth day.

More dilute solutions of perchloride were now used, and the spores exposed to them for longer time.

(β.) Spores derived from blood of a guinea-pig dead of virulent anthrax, which had been grown for five months on Agar-Agar mixture, were mixed with solution of sublimate 1 in 1000, and kept so mixed for 5 hours, and for 24 hours. Samples of each were then inoculated into nutritive medium (broth peptone), and samples of each into guinea-pigs. [Similar spores that had not been exposed to sublimate were tested for control by inoculation into a guinea-pig, and they produced fatal anthrax in two days.] The inoculated tubes showed no growth, the guinea-pigs remained perfectly well.

(γ.) Spores derived from blood of a guinea-pig dead of virulent anthrax that had been grown for four weeks on Agar-Agar mixture (at the end of the four weeks spores occurring in the cultures were found to be virulent) were mixed with solution of sublimate 1 in 1000, kept so for one hour, and then inoculated into several tubes of broth peptone, and into one guinea-pig. One of the tubes showed, after three days of incubation at 35° C., good and typical growth of bacillus anthracis. Of this subculture a few drops were inoculated into two guinea-pigs,

with the result that both were dead of typical anthrax within 48 hours. The guinea-pig inoculated with the spores acted upon by sublimate solution, however, remained well.

It would appear from this experiment that although most of the spores used had been killed by the sublimate after one hour's exposure, there were some that had escaped, and hence in one tube growth of anthrax bacilli which, as the experiment proved, were possessed of perfect virulence.

(δ.) Spores from a culture in broth peptone started two months before with "spores," were tested by inoculating a guinea-pig; the animal was dead of typical anthrax on the third day.

Similar spores were mixed with sublimate solution 1 in 1,000, and kept so for one hour and for four days, and tubes of broth peptone and guinea-pigs (two for each sample) were inoculated with them. All tubes produced normal growth of bacilli anthracis which proved virulent, and all four animals were found dead on the fourth day of typical anthrax.

(ε.) The same spores as above were mixed with sublimate 1 in 10000, and were then used in precisely the same manner (*i.e.*, after one hour and after four days) as in the preceding experiment for inoculation of tubes of broth peptone and of guinea-pigs. All tubes had good growth of virulent bacilli anthracis, and all the inoculated animals died of typical anthrax,—some were dead on the third, some on the fourth day.

(ζ.) Spores derived from the blood of a guinea-pig dead of typical anthrax which had been grown in broth peptone for 16 days, and which proved virulent on inoculation of a guinea-pig, were kept mixed for one hour with sublimate 1 in 1000. Then several tubes of broth peptone and certain guinea-pigs were inoculated with the mixture; all the tubes showed typical and copious growth of bacillus anthracis after three days. This growth was tested on two guinea-pigs, which died of typical anthrax within two days.

It would appear, then, from the facts and observations I have recorded, that solution of sublimate of the strength of 1 in 480 has not the power to destroy by exposure to it for 15 minutes all spores of bacillus anthracis. In a solution of the strength of 1 : 1000 it is capable of killing certain spores if they were left in it for five hours. But, on the other hand, there were anthrax spores which proved much stronger, since even after an exposure for four days to the sublimate solution of 1 in 1000, they were found to be living, and capable of germinating and of killing animals. Again, exposure for one hour in this strength of solution, although capable of killing many similar spores, did not suffice to kill all.

The specific statement, therefore, of Koch (*l.c.*, p. 277) that a solution of sublimate of the strength of 1 in 5000 kills the spores of bacillus anthracis if only they be moistened with it for a few minutes; and his further general statement (*l.c.*, p. 278) that a disinfecting fluid containing sublimate in solution of the strength of 1 in 5000 can be relied on for "perfect disinfection," since it suffices to annihilate all life of micro-organisms and their germs within a few minutes, get no support whatever from the facts I have observed. In my hands neither the spores of bacillus anthracis nor spores of bacillus subtilis were killed with any degree of certainty when subjected for one hour to a solution containing sublimate 1 in 1000; in one series of experiments even 1 in 480 failed to kill the spores after an exposure of 15 minutes.

This difference in results cannot be due to the organisms in my experiments not having been brought thoroughly in contact with the disinfectant. For as I have already noted, in all my experiments, those which are to follow as well as those already recorded, a trace only—a

fraction of a droplet—of the culture containing the organism to be used was mixed with about 100 times its amount of the sublimate solution; and as was proved over and over again by microscopic examinations, the organisms in the mixtures were well isolated.

The clue to the difference is in the media in which the several samples of spores used in my experiments had been developed. Thus spores grown on solid Agar-Agar mixture (experiments β and γ) proved to have a decidedly lesser resistance to the sublimate than those grown in fluid broth peptone (experiment δ). This is in harmony also with the observations already recorded in reference to the spores of bacillus subtilis.

Sporeless bacillus anthracis was next dealt with.

Killing power on sporeless anthrax bacilli sub-culutres;

In reference to sporeless bacillus of cultures I have pointed out in my report for 1881 that if a culture of bacillus anthracis, no matter its source, is made in fluid medium (broth), the growth, as a rule, after two or three days' incubation, is noticed as a whitish, loose, fluffy mass (consisting of threads of anthrax bacilli, some straight others twisted and coiled); that this growth increases in bulk as long as the nourishing ingredients of the culture last, but always remains in the depth of the fluid; and that so long as this is the case *no spores* are ever formed in these anthrax threads. But if by some means or other the growth finds access to the surface of the fluid, and remains there,—as, for instance, in consequence of cottonwool fibres sustaining it or by portions of the growth adhering to the glass,—spore formation will take place in the growth that is on the surface. For experimental purposes, therefore, it is necessary, in order to be quite sure that no spores are present, to select bacillus growth from culture tubes only in which there is no sign of growth on the surface; cultures, that is, in which the whole mass of anthrax threads is limited to the bottom of the test tube.

For my experiments samples of sporeless bacillus anthracis were used as follows :—

(*a.*) Bacilli of *a culture* in broth 24 days old, which had been started from blood of guinea-pig dead of anthrax, were mixed with a solution of perchloride of mercury of the strength of 1 in 25000, and kept therein for 35 minutes and for 60 minutes respectively; then tubes of broth and guinea-pigs were inoculated with samples of the mixture. All the tubes showed typical virulent growth after two to three days, and all the inoculated animals died of anthrax on the second to third day.

(*b.*) A sample of a culture in broth three days old of blood bacillus was subjected for 30 minutes to the action of sublimate solution 1 in 25000. Two guinea-pigs were then inoculated with drops of the mixture. One of the guinea-pigs died within 30 hours of typical anthrax; the other died after 14 days, but no bacilli could be found in its blood or spleen.

(*c.*) The experiment was repeated with a solution of sublimate 1 in 20000. Result, no illness occurred in the guinea-pigs inoculated.

From this it appears that sporeless bacillus of a given culture is not killed by sublimate 1 in 25000, but that a solution of 1 in 20000 does destroy its germinating power.

in blood.

Experiments were now made with bacillus anthracis of the *fresh blood* of a guinea-pig dead of anthrax. In all of them the anthrax animals which furnished the blood had been dead only a few hours.

(A.) Experiments with solution of perchloride of mercury 1 in 10000.

1. Samples of the blood of a guinea-pig dead of anthrax, abounding in bacilli, were kept mixed with the above solution for 10, 20, and 30

minutes respectively. Then tubes of broth and guinea-pigs were inoculated with these samples. No growth followed in any of the tubes, and all the animals remained well.

Killing power on blood-bacilli of anthrax.

2. Blood of a second guinea-pig dead of anthrax and full of bacilli was mixed with the above solution. After 30 minutes two guinea-pigs and several tubes of broth were inoculated. None of the animals died, and the tubes remained free of growth.

3. Blood of a third guinea-pig dead of anthrax and full of bacilli was kept mixed with the above solution for 10 and for 20 minutes. With samples of these mixtures tubes of broth and guinea-pigs were inoculated. In all the tubes vigorous growth developed of virulent (as tested by experiment on guinea-pigs) bacillus anthracis, and all the animals were dead of anthrax between the second and third day.

4. Blood of a fourth guinea-pig dead of anthrax and full of bacilli was mixed with the above solution and kept so for 30 minutes. No result followed on inoculation of tubes and of animals.

From these experiments two facts are clearly evident: First, a solution of perchloride of mercury of the strength of 1 in 10000 kills, without fail, bacilli of anthrax blood if allowed to act on them for 30 minutes; shorter periods, 20 and 10 minutes, do not always suffice, since in one experiment (3) the bacilli were not killed. The disinfecting power, therefore, of sublimate 1 in 10000 is to be trusted if the latter be allowed to act for 30 minutes. Secondly, the mercurial solution being the same in all experiments, the proportion of anthrax blood in sublimate solution being also always about the same, and the animals inoculated with the mixture, but not killed, being found in subsequent experiments to be fully susceptible to anthrax,—there is but one explanation of the differences observed as regards the resisting power of separate samples of bacilli each exposed to the sublimate solution for 10 and 20 minutes, viz., that the bacilli from the blood of different guinea-pigs recently dead of typical anthrax have not all of them a like power of resistance to the disinfectant. In other words, bacilli thus treated, although liable to produce fatal anthrax in guinea-pigs, are not uniformly fatal to these animals.

Operation of pedigree in result.

In a former report I have pointed that there can be no doubt about the fact that anthrax bacilli of different sources possess different degrees of virulence. I have there shown that while the blood of a white mouse dead of anthrax is capable on inoculation of killing white mice and guinea-pigs, it is not capable of killing sheep; also that while blood of guinea-pigs dead of anthrax is capable of killing guinea-pigs and sheep, it is not capable of killing cattle. And, again, I have pointed out that while Pasteur's vaccine charbonneux does not kill sheep or cattle it does produce fatal anthrax in mice and guinea-pigs.

Now, it is quite conceivable that two samples of blood bacilli from different sources, notwithstanding that both are capable of producing fatal anthrax in the guinea-pig, may nevertheless differ in their virulence (to the extent, for instance, that while one can the other cannot kill sheep). And if this be true of given blood bacilli, it may be true also of their descendants, and with the result that two strains of anthrax infectivity may be transmissible side by side, differing from one another in degree of virulence, and the least virulent of them capable of producing fatal anthrax in some animal or other.

The question, therefore, arises,—Is the above difference in resisting power of different blood bacilli ascribable to their immediate or to their remote ancestry?

As mentioned above, sublimate solution of the strength of 1 in 10000 and acting for 10 or 20 minutes had no effect on a given blood bacillus,

while the same solution in another experiment killed a different blood bacillus under like conditions of time.

Looking at my notes, I find that in series (3) when the sublimate solution failed to produce any effect on the blood bacillus, the experimental blood was that of a guinea-pig, which I will call *x*, dead on the third day after having been inoculated with blood of anthrax guinea-pig *y*, which blood had previously been kept mixed with sublimate solution of the strength of 1 in 25000 for 30 minutes. Guinea-pig *y*, on the other hand, had been inoculated with culture of blood bacillus grown in broth at 35° C. for two days (a culture of a sort which I know from many observations to be very virulent); and guinea-pig *y* had been found dead of typical anthrax on the third day.

In the other series (1), where the sublimate solution did kill the blood bacilli, the history of the bacilli is as follows:—The blood furnishing them was derived from a guinea-pig, which I will call *m*. This animal had been inoculated, six days before its death by anthrax, from a culture set going from spores in a mixture of gelatine and sublimate 1 to 10000 and grown there for two days. These spores had been derived from a culture of bacillus in Agar-Agar five months old. Now, from observations already recorded in connexion with the action of sublimate on spores, it is evident that spores formed in cultures of Agar-Agar have not the highest degree of resistance to the sublimate, whereas I have ascertained by many experiments that bacilli of cultures in broth are both resistant and very virulent. And further, the offsprings of the above spores from Agar-Agar mixture had been produced not in a normal nutritive medium, but in one which contained sublimate, *i.e.*, had been produced under conditions somewhat unfavourable to their development; and as matter of fact these offsprings, though they on inoculation into a guinea-pig killed the animal with anthrax, did not kill it until six days after inoculation, the normal time being the second to third day.

Upon the whole, therefore, I think that we are justified in suspecting that the bacilli of the two sorts of blood were of different degrees of virulence, *owing to the differences in their pedigrees;* and that the sample* which resisted the action of the sublimate solution did so by reason of its having been derived from a more virulent original source than the other.

(B.) Solution of perchloride of mercury 1 in 20000.

1. Samples of blood of a guinea-pig that had died of typical anthrax on the third day after inoculation were mixed with the above solution of sublimate for 10, 20, and 30 minutes. The several samples were then inoculated into tubes containing broth and into guinea-pigs. The result was that the tubes inoculated with the first sample (10 minutes) showed good growth of active and virulent bacilli anthracis, whereas the other tubes remained free of growth. The guinea-pigs inoculated with the first sample died at the end of the second day, whereas those inoculated with the other samples (20 and 30 minutes) remained well.

2. Blood of a second guinea-pig dead of anthrax was kept mixed with the above sublimate solution for 30 minutes. Samples of the mixture were then inoculated into two guinea-pigs. One animal died on the eighth day of anthrax, the other remained well.

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* That the sublimate solution 1 in 25000 had no effect on the blood of guinea-pig *y* is shown by the fact that guinea-pig *x* inoculated with this mixture died of typical anthrax in the normal time.

Killing power on blood-bacilli of anthrax.

3. Blood of a third guinea-pig dead of anthrax was mixed with the above sublimate solution for 30 minutes. Samples of the mixture were then inoculated into two guinea-pigs. Both were dead of typical anthrax before the end of the second day.

4. Blood of a fourth guinea-pig dead of anthrax was kept mixed with the sublimate solution for 60 minutes. Samples were then inoculated into test tubes containing broth and into two guinea-pigs. The tubes showed, after three days, good growth of active virulent bacilli anthracis, and both animals were dead of anthrax before the end of the second day.

5. Blood of a fifth guinea-pig [*i.e.*, one of the guinea-pigs dying as the result of experiment 3 of the previous series (sublimate 1 in 10000)] was kept mixed with the sublimate solution for 10 and for 20 minutes. Tubes then inoculated with samples showed good growth after three days, and guinea-pigs inoculated therewith died of anthrax in the usual time.

It follows, then, from these experiments that solution of sublimate 1 in 20000 is not to be relied on as a disinfectant for the bacilli of blood even after 60 minutes' action.

Further, as to pedigree of bacilli.

In this series we once again meet with a difference as to the resisting power of blood bacilli according as they are derived from different guinea-pigs. Thus we see that in experiments 1 and 2 the blood bacilli acted upon by the sublimate for 20 and 30 minutes had been completely killed, whereas in experiments 3 and 4, bacilli similarly acted on for as long as 30 and even 60 minutes, remained perfectly unhindered in their action and retained full virulence. On comparing the antecedent histories of the infective materials used for producing anthrax in the guinea-pigs whose blood was employed for the above experiments, it appeared that as in the former series so in this, the anthrax material differed in virulence according to its original source, and that differences thus arising were maintained in subsequent transmission of the samples through guinea-pigs. This was manifested in their different resistance to the sublimate solution. In experiments 3 and 4 the guinea-pigs whose blood, after subjection to the sublimate solution, had killed other guinea-pigs, had been directly killed by anthrax as a consequence of inoculation with culture of blood bacilli in broth, *i.e.*, with virulent material, whereas the guinea-pigs whose blood was similarly used in experiments 1 and 2 and failed to kill other guinea-pigs, had died after inoculation with altered bacilli, *i.e.*, bacilli that had been subjected to the action of weak sublimate solution, and which had not produced death until a day or two later than normal virulent bacilli.

(c.) Solution of perchloride of mercury 1 in 25000.

A large number of experiments were made with blood bacilli of guinea-pigs dead of anthrax, after the bacilli had been acted upon by the above sublimate solution for varying periods of 10, 15, 20, 30, 60, and 100 minutes, with result as follows:—In all cases after an exposure for 10, 15, and 20 minutes the bacilli remained unaltered; similarly in some cases exposure for 30, 60, and even 100 minutes had no effect on the bacilli, guinea-pigs inoculated with them dying of typical anthrax before the end of the second day. But in other cases 30 minutes' exposure completely destroyed the bacilli. In one series of experiments a very instructive result was obtained, thus:—Blood bacilli were kept mixed with the above sublimate solution (1 in 25000) for 20, 30, and 60 minutes. Samples were then used for inoculation of guinea-pigs *a*, *b*, and *c*. Blood bacilli of the same source, which had not been exposed to the sublimate, were tested at the same time on a guinea-pig, and the animal died of anthrax on the third day.

The other three guinea-pigs also died of anthrax, but with this difference: guinea-pig *a* died on the third day (normal time), guinea-pig *b* on the fourth, and guinea-pig *c* on the fifth day. (These three animals were of about the same size and age.) So that in this series there was after 30 and 60 minutes a distinct though slight effect of the sublimate solution on the blood bacilli. Upon the whole, however, a solution of sublimate of the strength of 1 in 25000 is not, even after 100 minutes' action, a reliable disinfectant for blood bacilli of a guinea-pig.

More as to operation pedigree of bacilli.

In the above results there is again seen a striking difference in the resisting power of blood bacilli; for in some cases not even 100, minutes' exposure to the sublimate could hinder in the least the action of the bacilli. As illustration, I will cite two experiments:—in one, 30 minutes' exposure completely killed the bacilli; in the other,100 minutes' exposure had not the least effect on the bacilli. In the former experiment the blood was taken from a guinea-pig which I will call *n*; this animal had died after having been inoculated two days previously with blood of an anthrax guinea-pig *o*, and guinea-pig *o* had been infected two days previously with blood from a guinea-pig *p*. This guinea-pig *p* had been infected with spores of an Agar-Agar culture six months old, and had died on the third day after inoculation. In the latter experiment the blood was taken from a guinea-pig, which I will call *r*. This animal *r* had been infected with blood of a guinea-pig *s*, and *s* had been infected with blood of a guinea-pig *t*. This animal *t* had been infected with spores and bacilli of a culture in nutrient gelatine nine days old. A good deal of the gelatine had become liquefied and numerous spores were present. The animal died before the end of the second day.

In these two experiments we have, then, to deal with two strains of bacilli, each of which had passed successively through three guinea-pigs; strain number one was originally derived from a culture in Agar-Agar six months old, and strain number two from liquefied nutrient gelatine nine days old. The former, as was shown in previous experiments, had at the outset a less resisting power to sublimate than the latter, and this contrast between the two strains was maintained by the bacilli after they had passed successively through three guinea-pigs.

Sheep differ from rodents in susceptibility to medicated anthrax.

Several experiments were made in which blood bacilli of guinea-pigs dead after inoculation with virulent spores were exposed to the action of solution of sublimate of the strength of 1 in 30000, 1 in 40000, 1 in 50000, and 1 in 100000; the length of exposure being in all cases 30 minutes. In no instance was there any effect produced on the bacilli; guinea-pigs inoculated with the mixtures died of typical anthrax in the usual time.

In the preceding experiments it has been noted in several instances that guinea-pigs which had been inoculated with anthrax virus that had been acted upon by a solution of sublimate, remained well. All these animals, it deserves to be further noted, were subsequently tested as to their susceptibility with virulent anthrax material (spores or broth culture), and in all instances they succumbed to anthrax. Some of the animals had been inoculated previously more than once with mixture of sublimate and blood bacilli and had shown no illness; but on inoculating them with pure virus they, as I have said, promptly succumbed. I have had eight such guinea-pigs, and I think I am justified in saying that no immunity can be produced in guinea-pigs by inoculating them with medicated anthrax. This is in harmony with my former observations (see these reports, 1881).

But it is different with sheep. As is well known, sheep inoculated with Pasteur's vaccine charbonneux, premier and deuxième, with-

stand in the great majority of instances such inoculation, and are, moreover, rendered proof against it by inoculation with virulent anthrax material.

Now, blood of a guinea-pig dead of virulent anthrax kills sheep, but it is quite possible to imagine that the blood of such a guinea-pig, if exposed for a short time to the action of a definite sublimate solution, may lose some of its virulence; remaining, however, sufficiently virulent to kill guinea-pigs, though losing just so much of its virulence as to fail in killing sheep. And it will be remembered from a former report (that for 1883) that a sheep requires a stronger virus for production in it of fatal anthrax than a guinea-pig; there is a possibility therefore that a given sample of anthrax material may produce fatal anthrax in the latter while failing to produce the same result in the sheep,—as do blood of an anthrax mouse, and vaccine charbonneux of Pasteur.

The following experiments were therefore instituted with a view of ascertaining whether protection of sheep can also be obtained by using for the inoculation of these animals blood of guinea-pigs (dying in consequence of inoculation with anthrax) which has previously been subjected to the weakening influence of a certain solution of sublimate, and with the following results:—

By taking the blood of a guinea-pig dead of virulent anthrax as a result of inoculation with virulent material (*e.g.*, with spores grown in broth or in broth peptone, or with blood of a guinea-pig dead of anthrax after inoculation with spores), and mixing it with solution of perchloride of mercury 1 in 25000, and keeping it so mixed for 10 minutes, we do in fact obtain a material which on inoculation into guinea-pigs produces fatal anthrax, but which is powerless to kill sheep.

Two sheep were experimented upon, each receiving subcutaneously one Pravaz syringe full of this mixture.

There was noticed the day following, rise of temperature in one animal by 1 degree, in the other more than by 1·7 centigrade, and at the place of inoculation there was a painful swelling, which passed away by the end of the week.

The two sheep were then again inoculated subcutaneously, this time with one syringe full of blood diluted with equal part of water; the blood having been derived from a guinea-pig that had been inoculated with virulent material (culture of blood bacilli in broth), and which had died before the end of the second day.

These two sheep remained perfectly well.

The same animals were after the lapse of further ten days inoculated with a syringe full of anthrax blood, but without the slightest effect.

Three other sheep were inoculated with blood (derived from a guinea-pig dead before the end of the second day in consequence of inoculation with anthrax spores grown in broth) which had been kept mixed with solution of perchloride of mercury, 1 in 25000 for 15 minutes.

There was slight rise of temperature during the following day only; in one sheep of 0·5, in the second of 0·7, in the third of 0·2 degree centigrade. No swelling occurred at the seat of inoculation. After the lapse of four weeks each of the three animals received subcutaneously one syringe full of a mixture of virulent anthrax blood and solution of sublimate 1 in 25000 that had been made 15—20 minutes previously. No change whatever followed in these sheep. After the lapse of another week the three sheep received subcutaneously half a syringe full of virulent anthrax blood undiluted. Again no result followed. After further five days they received subcutaneously a good dose of a culture containing spores of anthrax. Still no result.

It follows, then, from these experiments that if sublimate solution of the strength of 1 in 25000 is allowed to act on virulent blood bacilli for 10 to 15 minutes, the bacilli become incapacitated from producing virulent anthrax in sheep ; and that sheep inoculated with such a mixture become protected against subsequent infection with virulent anthrax material.

It must be borne in mind, however, that the blood employed for the experiment must be fully virulent, *i.e.*, must be derived from a guinea-pig directly or indirectly infected with anthrax of a virulent source, *e.g.*, spores of a broth culture, or blood bacilli of a first or second remove therefrom.

In order to insure success on a large scale, as, for instance, for the protection against anthrax of whole flocks of sheep, I would suggest "vaccination," to be carried out in the following manner :—

Virulent anthrax material, say a culture in broth or broth peptone containing spores, should be used to inoculate a guinea-pig ; the blood of this animal can then be used at once, after medication, for inoculation of sheep, or it can be transmitted through one or more guinea-pigs successively, and the blood of each of these animals when dead of anthrax (which ought to occur before or at the end of the second day) can, after having been similarly medicated, be used for inoculation of sheep.

The blood to be thus used should be mixed with about 100 times its volume of sublimate solution of the strength of 1 in 25000 (or one grain in about fifty ounces of distilled water), kept so mixed for 10 to 15 minutes,* and then half to a whole hypodermic syringe of the mixture should be injected under the skin of the groin or inside of thigh of each sheep. To make sure of success the injection should be repeated after one week with the same kind of mixture, *i.e.*, fresh blood of a guinea-pig dead of virulent anthrax kept mixed for 10 to 15 minutes with solution of sublimate 1 in 25000. I in two instances succeeded in protecting sheep, in which the second vaccination was made with fresh virulent anthrax blood kept mixed for 10 minutes with solution of sublimate 1 in 30000, or 1 grain to about 60 ounces of distilled water. This is comparable to Pasteur's process of injecting vaccine charbonneux deuxième, which is alleged to be of higher degree of virulence than vaccine charbonneux premier, on account of its having been (as he says) exposed for a shorter period to the high temperature 42–43° C.

It is obvious that the mode of "vaccination" I have recommended, and which I am convinced is as effective as that with Pasteur's vaccine charbonneux, may in practice be easily carried out. And it does not require any special artificial cultivation carried out by experts for a definite number of days at a constant temperature of 42–43° C. The chief requisite is a guinea-pig dead of virulent anthrax; the further procedures, viz. :—the preparation of the proper sublimate solution, the mixing of this in sufficiently large quantity with the blood of the guinea-pig, and the injection of this mixture by means of a hypodermic syringe, being matters which obviously demand no special skill.

Varying my own experiment somewhat on two other sheep, I used for the first vaccination virulent blood of guinea-pig kept mixed for 10 minutes with sublimate solution 1 in 30000. No result followed. After five days I used for second vaccination virulent blood of guinea-pig kept mixed for

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* In order to avoid using particles of coagulated blood in which bacilli having become enclosed may thus escape being properly acted upon by the sublimate solution, it is necessary that after well mixing the blood with the sublimate solution, the sediment should be allowed to settle and the supernatant fluid should be poured off from it and the latter alone used for inoculation.

five minutes with sublimate solution 1 in 40000. One of the sheep had on the third subsequent day much swelling at the seat of inoculation, its temperature rose to 42° C., and the animal became very ill. The temperature fell on the fourth day to 40·8 C., then to 40·2 C., on the thirteenth day, however, the temperature had risen again to 41·9 C., and the sheep was found dead on the fourteenth day. No bacilli could be detected with the microscope in the blood or spleen of this sheep. The latter organ was small; the kidney was swollen, and much hyperæmic. With spleen pulp and with blood of kidney of this sheep I inoculated in each instance two guinea-pigs. All four animals were found dead of anthrax at the end of two days.

Now this sheep showed in both lungs numerous minute nodules of round cells caused by strongylus filaria, and the liver was extensively adherent to the diaphragm by old fibrous membranes in several places.

The second sheep of this series died after 15 days. It presented the same anatomical appearances in the lung, liver, and spleen as the other; but during life (except on the day immediately preceding death) it had shown no anthrax symptoms.

We see, then, from these experiments, that in two sheep, previously the subjects of a chronic disease, injection of the above rather strong second vaccine produced death after 14 and 15 days respectively. This is a result precisely analogous to that obtained in Hungary with Pasteur's deuxième vaccine charbonneux, for in that case sheep which were affected with a chronic malady succumbed to anthrax after some days.

From the fact that in our two sheep the elevation of temperature following on the second vaccination (*i.e.*, blood and sublimate 1 in 40000 for five minutes) had passed off after a week, it is justifiable to assume that had the animals been otherwise healthy no fatal result would have ensued. But bearing in mind that this chronic disease (caused by strongylus) is not at all uncommon in sheep—and that other chronic diseases to which sheep are subject may probably act in the same way—it is as well to use for second vaccination, blood that has been kept mixed with a somewhat stronger solution of sublimate than the one used in the above experiments. For this purpose I should recommend a solution of 1 in 30000 to 1 in 25000, *i.e.*, 1 grain of corrosive sublimate to between 50 and 60 ounces of distilled water.

I have not had opportunity of making similar vaccinations on cattle; but knowing that cattle require stronger virus than sheep, I should think that for them the fluid for the first vaccination might be virulent guinea-pigs' blood kept mixed for 10 to 15 minutes with sublimate solution of a strength of 1 grain in 70 ounces; and for second vaccination, virulent guinea-pigs' blood kept mixed for 10 minutes with a solution of 1 grain of sublimate in 100 ounces of distilled water.

Effect of proteid on results.

The disinfecting power of sublimate used, as in the experiments hitherto mentioned, in watery solution, is considerably greater, as might naturally be expected, than when mixed with a proteid solution; for in the latter case part of the sublimate, if not the whole of it, combines with other substances.

The following experiments illustrate this:—

(1.) Blood of a guinea-pig dead of anthrax was mixed with broth to which watery solution of sublimate had previously been added; the amount of sublimate present was estimated to be equal to 1 in 10000 of the total mixture. Samples of the blood and sublimate solution having been kept for 30 and 60 minutes respectively, were injected into guinea-

pigs. These animals were dead of anthrax before the end of the second day.

The blood bacilli of the same guinea-pig were completely killed when subjected for 30 minutes to a watery solution of sublimate of the strength of 1 in 25000.

(2.) The blood bacilli of the same guinea-pig were then mixed with broth sublimate, containing nominally 1 sublimate in 1000 of fluid. Time of exposure 30 and 60 minutes respectively. Result: The bacilli became completely inert.

(3.) The blood bacilli of the same guinea-pig exposed for 30 minutes in a mixture of nutrient gelatine (liquefied by warmth) and watery solution of sublimate, containing sublimate 1 in 10000 were all killed.

(4.) The blood bacilli of the same guinea-pig exposed for 30 minutes in a mixture of nutritive gelatine and sublimate, containing sublimate 1 in 20000, were only very slightly, if at all, affected; guinea-pigs inoculated with them died of anthrax on the third day.

We see, then, from these experiments that one and the same kind of blood bacillus was completely killed by a watery solution of sublimate of the strength of 1 in 25000, whereas it remained unaffected by a solution of sublimate in nutrient gelatine of the strength of 1 sublimate in 20000 of fluid, or even by a solution of sublimate in broth of the strength of 1 of sublimate in 10000 of fluid. I may add here that neither the gelatine sublimate nor the broth sublimate solution showed any trace of a precipitate when they were made by mixing together the nutritive material and the watery solution of sublimate; the fluids remained quite limpid, and all the sublimate therefore was in solution. The mercury could not, however, have been present as sublimate, but as some soluble combination, since the disinfecting action of the fluid became altogether altered.

Restraining power of mercury over anthrax.

Passing now to examination of the restraining power of sublimate on anthrax.

The restraining power of corrosive sublimate on spores and bacillus of anthrax was tested on the same plan as that used for the non-pathogenic organisms already dealt with, viz., a given volume of nutritive gelatine or broth was mixed with a definite volume of a given watery solution of the sublimate, and the mixture having been inoculated with the spores or with the bacilli of anthrax was exposed in the incubator. Gelatine mixtures were incubated at 19—20° C, broth mixtures at 35° C.

(1.) Spores of bacillus anthracis grown in broth.

A large number of experiments were made with spores. These were sown in fluid medium (broth or broth peptone) and in tubes containing solid nutritive gelatine sublimate, having been previously added to each in the proportion of 1 in 1000, 1 in 10000, 1 in 20000, 1 in 25000, 1 in 30000, 1 in 40000. As a general result it was found that growth of bacillus anthracis did not take place in these media; sublimate in these proportions having, as a rule, an inhibitory action on the germination of the spores. But in a few instances gelatine sublimate, even when containing the salt in she proportions of 1 in 10000, did not exhibit this restraining power, since the spores germinated in it and produced a crop of typical bacillus tnthracis. These crops were, however, not only late in making their appearance, but always when they did occur remained very limited in amount, as compared with a growth started at the same time with the aame spores in normal nutritive gelatine.

Reduction of morbific power.

Another important peculiarity of this retarded growth was this; namely, that though guinea-pigs inoculated with it died of anthrax, their death was considerably delayed. Thus, in one case a sample of the

growth in such a tube of gelatine-sublimate five days old having been inoculated into a guinea-pig, the animal did not die from anthrax until the sixth day; and using the same growth five days later for inoculation of a guinea-pig, no result was obtained. In another instance in which the growth was used on the third day, it produced death in the guinea-pig on the fifth day. It was used again on the eighth day for inoculation of a guinea-pig; and the animal died on the ninth day. This mitigation of virulence was maintained even in the next subculture of the same bacillus made in normal nutritive gelatine; for this used after five days' incubation for inoculation of a guinea-pig produced death of the animal from anthrax on the fourth day. But using another sample of the same subculture after 13 days, for the inoculation of another guinea-pig, *spores having in the meantime made their appearance*, death from anthrax was produced in the normal time, *i.e.*, at the end of the second day.

An observation worth recording, of a particular growth started with spores in gelatine sublimate (1 in 10000), is this: Examining the culture from time to time it was found that the maximum amount of growth was reached at the end of the first week; afterwards the growth did not increase in amount. Microscopic preparations made of this growth showed that before the end of the first week degeneration (described in my report for 1881) of many of the anthrax bacilli and threads had set in; this gradually affected the whole growth, so that before the end of the second week most if not all bacilli were degenerate, and new subculture in normal nutritive medium could not be started with them.

This observation along with the above facts as to their gradually diminishing virulence is strongly suggestive, that with time such a growth may lose its infective power for guinea-pigs; that, for instance, in the first week it will be capable of producing fatal anthrax, though the death of experimental animals will be delayed more and more the older the culture, and that finally ability of such growth to produce anthrax will be altogether lost.

In two instances of tubes of gelatine containing sublimate 1 in 1000 that had been inoculated with spores I have noted after the end of a week just the faintest trace of a growth of bacillus. This was indicated also by the gelatine having, as in normal tubes, become liquefied; but the extent of this liquefaction was incomparably larger than the very small amount of growth would have led one to expect.

Gelatine sublimate 1 in 50000 has no marked restraining influence on spores of bacillus anthracis. A copious growth possessing normal infective power was produced in it.

To sum up, then, sublimate in nutritive gelatine in the proportion of 1 in 10000 to 1 in 40000 does not always prevent anthrax spores from germinating and producing there a crop of bacilli; but in those cases in which such amount of sublimate failed to inhibit their germination and growth the salt had nevertheless a certain restraining influence, since the growth was retarded, was very small in amount, and its infective power was diminished; and moreover, this diminution of infectivity increased with time until its total extinction was achieved. But gelatine sublimate 1 in 50000 and in lesser proportion has no restraining power.

It is necessary to note that I am quite unable to reconcile these observations of mine with those experiments of Koch in which 1 in 300000 of the sublimate altogether inhibited the germination of anthrax spores, and 1 in 600000 markedly restrained their growth. The only way that I can account for this discrepancy is that perhaps there may have been an error in Koch's calculation of the amount

of sublimate present in his nutritive mixture; that instead of using, as he thought he did, a certain strength of sublimate solution as admixture to the nutritive medium, he did by error of his assistant actually use a solution tenfold stronger then he had proposed to use, or else had added the sublimate solution to a tenth part of the quantity of nutritive material he had intended. Upon this supposition the discrepancy tends to disappear, for instead of having a mixture containing sublimate 1 in 300000 he would actually have had a mixture containing sublimate 1 in 30000; and for a mixture containing nominally sublimate 1 in 600000 he would actually have used one containing sublimate 1 in 60000. Accepting this explanation and making at the same time allowance for a difference in resisting power of the spores used by Koch and myself (for Koch used spores dried on silk threads while I used very virulent spores of fluid medium), I am disposed to think that the discrepancy in our results completely disappears.

As regards *sporeless* bacillus anthracis.

Blood bacillus (of guinea-pig) inoculated into tubes of nutritive gelatine containing sublimate 1 in 10000, 1 in 20000, 1 in 30000, and 1 in 40000, did not, as a rule, produce growths of the organism, although I have noted occasionally slight growth of bacilli in sublimate and gelatine of even 1 in 20000.

In a solution of 1 in 50000, however, such bacilli produced copious growth. But there was found a difference in the infective power of growths thus obtained; some produced death from anthrax in guinea-pigs in the normal time (second day), others as late as the fifth day. Looking in my note-book for the details of those experiments I find that in a case where the crop produced from blood bacilli in gelatine-sublimate 1 in 50000 possessed full infective power (*i.e.*, killed guinea-pigs before the end of the second day), the blood bacilli in question had been taken from a guinea-pig that had died before the end of the second day in consequence of direct inoculation with spores that had been grown in broth; whereas, in cases where the infective power of the crop of blood bacilli grown in gelatine-sublimate (1 in 50000) was mitigated, and death of the animals inoculated with it had been markedly retarded, the blood bacilli of the experiment had been taken from animals that had been inoculated with bacilli which had been exposed to watery solution of sublimate 1 in 25000 for 30 minutes.

These facts are in harmony with others already recorded in the preceding pages, viz., that anthrax bacilli obtained from different sources differ in their virulence and in their power of resistance to sublimate.

In concluding this section of the report I record a very simple experiment, demonstrating strikingly a great difference of resisting power to sublimate that exists between bacillus anthracis and some of the non-pathogenic organisms already reported on.

Two sets of tubes were prepared, one set containing nutritive gelatine and sublimate in proportion of 1 part sublimate in 25000 parts of the mixture, the other set containing broth and sublimate in like proportions; and of both sets two tubes in each instance were inoculated with the following organisms:—

(1.) Spores of bacillus subtilis.
(2.) Sporeless bacillus subtilis.
(3.) Commabacillus of Finkler.
(4.) Commabacillus of Koch.
(5.) The micrococcus of fæces of ape.
(6.) Spores of bacillus anthracis.
(7.) Bacillus anthracis of blood.

The fourteen gelatine-sublimate tubes were then exposed in the incubator to 19—20° C., and the fourteen broth-sublimate tubes to a temperature of 35° C.

At the end of several days the tubes were inspected and it was found that all of them had produced good and normal growth, with the exception of those inoculated with organisms 6 and 7, namely, with spores and with bacillus anthracis.

Experiments with Bacillus Septicæmiæ of Guinea-Pigs.

Bacillus Septicæmiæ.

[*See Plate XIX. at end of this paper.*]

Some time ago my colleague, Mr. A. Lingard, found on inoculating guinea-pigs with human tubercular sputum that some of these animals died in the course of a day or two. At the place of inoculation there was swelling owing to exudation of sanguineous but not odorous fluid. The blood of the heart contained bacilli, which, although numerous, were not by any means as numerous as in anthrax. There was exudation in the pleura and peritoneum, the viscera of the chest and abdomen were much congested and contained petechiæ on their serous surfaces; the spleen was slightly enlarged. The bacilli in the blood were motile, rounded at their ends, of about the length of tubercle bacilli, but somewhat thicker; they were single or in dumb-bells, strikingly shorter and thinner than the bacilli of anthrax and the bacilli of malignant œdema. The single bacilli were 0·0030 to 0·0054 mm. in length, and about 0·001 mm. in thickness; some of the dumb-bells were, however, twice this length, but rarely longer. That this disease is not the disease described by Koch as malignant œdema and which he produced by inoculation of garden earth, is conclusively proved by the size and the distribution of the organism.

Figure 25.

These bacilli grow well and rapidly in neutral and faintly alkaline broth, in broth peptone, and in meat extract peptone solution. These culture-fluids inoculated with the organism and exposed to a temperature of 35° C. show much turbidity in 24 hours. The turbidity rapidly increases during the next few days, at the same time a greyish voluminous sediment of bacilli is formed, and a loose not very coherent thin pellicle. Solid Agar-Agar mixture and blood serum inoculated on the surface become covered in two or three days with a whitish thick film. On nutritive gelatine the growth spreads rapidly in the course of several days over the surface in the form of a waxy-looking, thin, whitish, translucent film, its outlines irregular and crenated. Inoculated into the depth of the gelatine the resulting growth forms a whitish knobbed or even fluffy streak. It does not liquefy the gelatine.

Figure 27.

Examined microscopically the growth in broth peptone or meat extract peptone shows bacilli as single rods of similar dimensions to those in the blood, and others in the form of dumb-bells of rods, in many instances forming chains which are sometimes made up of dumb-bells of individuals looking as short as micrococci. These chains are wavy and move serpent-like. In cultures several days old the serpent-like moving chains made up of diplococci or of short rods form a very characteristic feature, and the several bacilli composing them, as well as the dumb-bells, are so short that they look very much like streptococci or diplococci respectively. Were it not that these septicæmic organisms are motile, and were it not for the intermediate forms between coccus-like chains and chains composed of rod-like elements, the organism could be easily mistaken for streptococcus.

Examining these serpent-like chains of cocci more carefully, it is seen, particularly in stained specimens, that the cocci are always arranged as dumb-bells placed end to end and separated by a clear bridge; the number of such dumb-bells determines the length of the chain; it is

Figure 26.

further seen that other chains, instead of being composed of diplococci, consist of rods, each rod of the length of a diplococcus of the above chains; and lastly there are chains, of which the elements are rods, but every one of them is constricted in the middle thus presenting an appearance intermediate between a rod and a diplococcus.

Some of the bacilli contain bright granules, one only in a single element; and these granules look very much like spores. Such "spores" are noticeable in the cultures of broth or other material as early as after 24 hours' incubation, and I have not missed them in any tubes; but in the blood of an animal dead of the disease I have not seen any indication of spores in the bacilli.

The small size of the bacilli found in the blood, and under culture, their size and arrangement, particularly the serpent-like chains of coccus-like bacilli, are sufficient to distinguish them from the bacillus of Koch's malignant œdema or Pasteur's vibrio septique. But there is this similarity of action between the two organisms, namely, that, as has been shown by Gaffky for cultures of the bacillus of Koch's malignant œdema, so also this bacillus requires always inoculation of comparatively large quantities of the culture fluid for production of death in guinea-pigs. In the case of this bacillus, a culture in broth or similar culture produces rapid death (*i.e.*, in one to three days), in guinea-pigs, if into them about 1–2 CC. of the culture fluid are inoculated subcutaneously. Inoculation of small quantities only—say several drops—produces a firm tumour at the seat of inoculation, which increases in size during the first week, and the animals eventually die, but sometimes as late as the 12th or 14th day. The more recent a culture the more likely it is to act virulently, even when used in small quantities.

Fresh blood taken from an animal that has died of the malady quickly produces virulent infection even when inoculated in small quantites.

The bacilli cultivated in nutrient gelatine were also tested on mice with the result that they act very virulently, since the animals inoculated under the skin die within 24 hours. The size of the bacilli, their mode of growth, and their distribution in the infected mice, prove them to be quite different from the bacillus producing Koch's septicæmia of mice.

Influence of mercury on them: *Killing.*

The killing power of sublimate in regard of this bacillus was now tested on samples of the organisms grown in broth peptone and in meat extract peptone.

(1.) Of a culture in broth peptone containing many spore-bearing bacilli, a small quantity mixed for 30 minutes with a watery solution of sublimate of the strength of 1 in 10000, was inoculated into two fresh tubes containing meat extract peptone solution which were then placed in the incubator at 35° C.

One of these tubes showed no growth after a fortnight; the other tube seemed to show a mere trace of something like a growth after two days, but this remained quite unaltered at the end of a fortnight; when then examined under the microscope no bacilli could be detected.

(2.) Of a similar culture in meat extract peptone (four days old) a small quantity was mixed for 30 minutes with watery solution of sublimate of the strength of 1 in 20000, and then inoculated into two tubes of meat extract peptone. After 24 hours there was good growth of the bacillus in one tube; in the other there was none at this date nor after three days. But at the end of a fortnight there was copious growth in both tubes.

With a sample of the culture produced in 24 hours I inoculated successfully a guinea-pig. The animal, which had a big tumour at the seat of inoculation after 48 hours, was found dead on the seventh day.

(3.) Of a culture in meat extract peptone (four days old) I took a small quantity and mixed it for 30 minutes with a watery solution of sublimate 1 in 20000, and then inoculated with it four tubes of meat extract peptone solution. Good growth of normal character followed.

From one of these tubes I inoculated on the third day and successfully two guinea-pigs.

From these experiments it follows that a sublimate solution of the strength of 1 in 10000 acting for 30 minutes destroys spores as well as the bacilli, but that one of the strength of 1 in 20000 acting for 30 minutes does not affect or injure either.

Restraining.

Restraining power of the sublimate as regards this bacillus.

(1.) Several tubes containing nutritive gelatine and sublimate, the latter in the proportion of 1 in 10000, were inoculated from a normal culture of the bacillus in broth peptone. No growth had appeared in any tubes after two weeks, while in normal nutritive gelatine tubes inoculated at the same time from the same culture there was typical and luxuriant growth of the bacillus.

(2.) A number of tubes of nutritive gelatine and sublimate, the latter in the proportion of 1 in 20000, were inoculated from several different cultures of the bacillus. In every one of these tubes there appeared in the usual time copious growth of the bacilli, having the same characters, both as to general appearance and copiousness, as tubes of normal nutritive gelatine inoculated simultaneously from the same cultures.

From these experiments it appears, then, that sublimate of the strength of 1 in 10000 has a decided, but that in a strength of 1 in 20000 it has no restraining power on these bacilli; and comparing the results of these experiments with those on spores of bacillus anthracis, we find that sublimate has a restraining power greater for the spores of bacillus anthracis than for those of this bacillus of septicæmia.

[These bacilli proved to be possessed of some very remarkable and interesting chemical functions, which form the subject of a separate report by Dr. Wooldridge.]

Experiments with the Streptococcus of Foot-and-Mouth Disease.

Streptococci.

I have made a few experiments to test the restraining power alone of sublimate on the streptococcus of foot-and-mouth disease, which is described in another report of this series.

(1.) From a normal culture of this organism in broth peptone I inoculated gelatine-sublimate 1 in 25000 and 1 in 30000. At the same time I inoculated from the same culture normal nutritive gelatine. While the latter medium developed good growth of the streptococcus the gelatine-sublimate media failed to develope any.

(2.) From a normal culture of the streptococcus in broth peptone I inoculated gelatine-sublimate: (*a*) 1 in 30000, (*b*) 1 in 50000, (*c*) 1 in 70000; (*a*) remained free of growth, (*b*) developed tardily a slight growth, and (*c*) developed normal growth in the usual time.

From these experiments it follows that the restraining power of sublimate on this streptococcus is slightly greater than on the sporeless bacillus anthracis.

In addition I have made a few experiments with another streptococcus derived from a peculiar disease in the cow connected with scarlatina in man (described in a special report), and I have found that the restraining power of sublimate on this streptococcus is still greater than on the streptococcus of foot-and-mouth disease.

Experiments with Tubercular Virus.

On the Action of Perchloride of Mercury on Bacteria; by Dr. Klein.

Tubercle bacilli.

I append to this report two tables,* giving the details of experiments made by Mr. A. Lingard to ascertain the killing power of perchloride of mercury on the tubercular virus. The results of these experiments show that a solution of sublimate of the strength of 1 in 960 completely destroys the infective power of the virus of human tubercle, if the latter be exposed to it for from four to eight hours. In the case of bovine tubercular matter, it was found that the solution of sublimate has not, short of eight hours' exposure to it of the organism, any killing power, but that after five hours' exposure a marked retardation of the subsequently induced tubercular disease is noticeable. In one case exposure to the sublimate for eight hours destroyed altogether the infective power of the virus; and nine hours exposure had this effect in both cases experimented on.

General results.

As a result of all the experiments which I have made with perchloride of mercury we arrive at the conclusion that its antiseptic or *restraining powers* and its *disinfecting* or *killing powers*, although not so great as claimed for it by Koch, are nevertheless, as Koch has contended, considerably greater than those of any other known chemical substance. We have further shown that these powers of sublimate differ widely for the different organisms investigated, and that it is not justifiable to apply the indications obtained from experiments on one species indiscriminately to all others; and least of all is it permissible to say that because sublimate has a certain power as regards the spores of bacillus anthracis it has equal power on all other organisms (spore-bearing and sporeless), since, as we have seen, the spores of bacillus anthracis are not the most resistant of organisms. Another and important point brought out by these experiments is the difference in resisting power of the offspring of one and the same species, according as it has been derived from different sources.

A marked contrast in resisting power to sublimate appears between certain obviously pathogenic organisms that we have examined and certain others not possessing pathogenic character, or in regard of which such character has not been clearly demonstrated. Non-pathogenic organisms possess a greater resisting power towards the sublimate than pathogenic.

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* On following pages.

TABLE I.

Human.

Tubercular material taken from human lung and mixed with a solution of mercuric perchloride (1 in 960 grns. $\frac{1}{16}$ to ʒi.) rubbed well up in a glass mortar (previously well washed in strong nitric acid), and strained through muslin.

Guinea-pigs.	Human Tubercular Matter.		Experimental Guinea-pigs.		
	Length of Time exposed to Mercuric Perchloride.	Date of its Inoculation into Guinea-pigs.	Date at which killed.	Pathological Appearances.	Days lived.
	Hours.	1886.	1886.		
a.	4	16th Feb.	22nd April	Perfectly healthy. Small spleen.	65
b.	4	„	„	Ditto.	—
c.	5	„	„	Ditto.	—
d.	5	„	„	Ditto.	—
e.	6	„	„	Ditto.	—
f.	6	„	„	Ditto.	—
g.	7	„	„	Ditto.	—
h.	7	„	„	Ditto.	—
k.	8	„	„	Ditto.	—
l.	8	„	„	Ditto.	—

Control guinea-pig 1 inoculated 16th February 1886, *died* 10th April 1886—50 days. Disease advanced. Spleen large.

„ „ 2 inoculated 16th February 1886, died of general tuberculosis.

The control animals were inoculated with the same tubercular matter as the above, but pure and not mixed with the sublimate.

TABLE 2.

Bovine.

Bovine tubercular material mixed with mercuric perchloride 1 in 960 grns. $\frac{1}{16}$ to 3i. Inoculated guinea-pigs as follows :—

Guinea-pigs.	Bovine Tubercular Matter.		Experimental Guinea-pigs.		
	Duration of Exposure to Perchloride.	Date of its Inoculation into Guinea-pigs.	Date at which Animal died or was killed.	Duration of its Life after Inoculation.	Pathological Appearances.
	Hours.	1885.	1886.	Days.	
a.	1	17th Nov.	12th Jan. - -	56	Well-marked tubercular changes. Spleen large.
b.	1	,,	6th Feb. - -	81	Ditto ditto.
c.	2	,,	6th March -	108	Ditto ditto.
d.	2	,,	15th Feb. - -	90	Ditto ditto.
e.	3	,,	17th Jan. - -	61	Ditto ditto.
f.	3	,,	9th Feb. - -	84	Ditto ditto.
g.	4	,,	1st Feb. - -	76	Ditto ditto.
h.	4	,,	Killed 22nd March	125	Ditto ditto.
k.	5	,,	24th Feb. - -	99	Ditto ditto.
l.	5	,,	Killed 22nd March	125	Ditto ditto.
m.	6	,,	,, ,, -	125	Ditto ditto.
n.	6	,,	,, ,, -	125	Ditto ditto.
o.	7	,,	,, ,, -	125	Ditto ditto.
p.	7	,,	9th March -	111	Ditto ditto.
q.	8	,,	1st March - -	103	Ditto ditto.
r.	8	,,	Killed 22nd March	125	Normal. Quite healthy in every respect. Spleen small.
s.	9	,,	,, ,, -	125	Ditto ditto.
t.	9	,,	,, ,, -	125	Ditto ditto.

Control guinea-pig 1 died after 52 days. General tuberculosis.
,, ,, 2 ,, 54 ,, ,, ,,
,, ,, 3 ,, 58 ,, ,, ,,

BACILLUS SEPTICÆMIÆ OF GUINEA-PIGS.

PLATE XIX.

FIG. 25.

From a preparation of the blood of a guinea-pig dead of septicæmia. Bacilli seen between the blood corpuscles. Magnif. power about 1250.

FIG. 26.

From an artificial cultivation in gelatine of the above bacillus septicæmia. Magnif. power 1250.

FIG. 27.

Artificial cultivation on the surface of nutritive gelatine of the bacillus septicæmia. Natural size.

Fig. 25.

Fig. 26.

Fig. 27.

No. 5.

Further Report on Mercury as a means of Prophylaxis to Anthrax; by J. T. Cash, M.D.

On Mercury as a Prophylaxis to Anthrax; by Dr. Cash.

In my last report to the Local Government Board I stated that I had by administering corrosive sublimate hypodermically to rabbits before inoculating them with anthrax, so far mitigated the disease resulting in them from the anthrax inoculation as to retard its fatal issue, and even to permit of recovery. A particular rabbit which recovered, completely withstood further inoculation with unmitigated virus on two separate occasions, at dates four and six weeks subsequent to primary inoculation.

Extension of research.

Best means of administration.

At the present time I shall refer briefly to an extension of the former experiment with regard to corrosive sublimate, and to the administration of other mercurial preparations, which it occurred to me might be substituted for it.

1. Inunction with ammoniated mercurial ointment.
2. Administration of red iodide of mercury subcutaneously.
3. Hypodermic injection of corrosive sublimate.
4. Hypodermic injection of red oxide of mercury.

1. *Inunction with Ammoniated Unguent of Mercury.*—We know from the researches of dermatologists, that a condition of ptyalism (salivation) is readily produced by the inunction of ointments of which mercury is a constituent. Not only is a general or constitutional effect thus produced, but it is found that in the case of syphilitic skin disease, a predominating local effect, parallel to the results obtained in the same disease by Hunter and Hebra with subcutaneous sublimate injection, is frequently to be observed as a sequel to mercurial inunction. There is in fact a local resistance produced "on the top of" constitutional effect, as a result of the mercurial application.

It occurred to me that one might employ with possible advantage the inunction method as a preparative to anthrax inoculation, the inoculation being performed in the seat of inunction. In order, however, that the anthrax virus might not be too rapidly carried into the general circulation beyond the local action of the drug, it seemed desirable to apply an Esmarch's ligature above the seat of inoculation in order that for one or two hours the subcutaneously inoculated anthrax might be detained in the more resistant area.

Death from mercurial inunction with symptoms of general wasting occurs in rabbits if the inunction be not employed with the greatest caution. I have seen it result after four inunctions of ·2 to ·25 grms. on each occasion of ung. hydrarg. ammon., the treatment occupying eight days.

Two inunctions of 3 grms. in the course of three days were fatal to a guinea-pig, which died the day succeeding the second application.

The plan of experiment was the following :—

An inunction of about ·25 grms. of ung. hydrarg. ammon. was made on the front of the clipped thighs of an animal (rabbit) every second or third day; after this treatment had continued for a certain time, an elastic Esmarch's ligature was applied round the upper portion of the thigh of the animal and inoculation was made subcutaneously within the area of inunction. In one to three hours the bandage was removed and the animal closely watched.

In one experiment ·9 grms. of the unguent had been employed in the preparation extending for 10 days, of a rabbit weighing 1,451 grms. Ten minutes after the last inunction, an Esmarch's ligature, which caused

the animal no inconvenience, was applied round the upper part of the thigh; after this application had been made anthrax blood was inoculated at the seat of inunction. The ligation of the limb was maintained for three hours, and the circulation was then restored by removal of the bandage. The animal died of anthrax in about 76 hours, outliving the control animal by about 20 hours.

Though I have seen an undoubted delay occur in the fatal issue of anthrax inoculation, as a result of inunction in rabbits, I have been unable so far sufficiently to gauge the administration of the drug by this method, as to make it seem desirable to prosecute its investigation further, in preference to more promising mercurial preparations.

2. *Red Iodide of Mercury.*—Guinea-pigs appear more tolerant of this drug than they are of the perchloride. The same daily dose was given. In one animal in which too much was administered, the symptoms were identical with those observed from too long exhibition of the perchloride, and it is probable that conversion into this salt takes place in the body. One guinea-pig, weighing 470 grms., received in 18 days (hypodermic injection every second day) ·01 grms. in all of the drug; a second, weighing 520 grms., in 45 days ·02125 grms. In the first animal death from anthrax occurred on the second day; in the second, the prepared animal outlived the control by more than 24 hours, and after death very few bacilli were present in its blood.

3. *Red Oxide of Mercury* suspended in mucillage has been strongly recommended by Watraszewski,* who found that in the case of individuals requiring an active mercurial treatment ·06 to ·16 grms. of the drug injected sustcutaneously at intervals of from six to eight days effected the purpose excellently.

I cannot speak from the few experiments I have made of such definite advantage as by analogy might have been anticipated from Watraszewski's clinical experience. Two administrations of the drug in the course of five days (amounting to ·03 grms.) to a rabbit of 1,200 grms. weight caused the death of the animal with marked marasmus (wasting). An inoculation with anthrax of a rabbit weighing 1,500 grms. which was not materially affected by the same dose did not result in any apparent change in the animal, although the control rabbit died in three days. As, however, re-inoculation, after the lapse of 14 days, was fatal to the former, we can at most attribute a very slightly increased resistance to the virus as a result of the administration of this drug.

Continued preference for perchloride.

4. *Perchloride of Mercury.*—From the brief resumé I have given of experiments conducted with salts of mercury, other than the perchloride, it will be seen that those do not contrast favourably with the results obtained with the last-named drug already published in last year's report.

(*a*) Recovery from anthrax,

I have followed up the investigation of the prophylactic action of the perchloride still further, and the favourable opinion I was before led to entertain of its efficacy has been abundantly confirmed.

A large rabbit, weighing 3,010 grms., received hypodermically in the course of 17 days a total of ·0125 grms. of corrosive sublimate. It was then inoculated with fresh anthrax blood of a guinea-pig which had succumbed to the disease (produced by inoculation of cultivation of bacilli) in 40 hours. The course of the temperature variation is given in the table.

A second (unprotected) animal was inoculated at the same time, and died of typical anthrax on the evening of the third day.

* Orig. Mit. Centralblatt f. d. medicinischen Wiennschaften, 1886, No. II.

	Protected.	Unprotected.
Morning before inoculation	= 38·1	38·4
Evening of day of inoculation	= 39·5	40·3
Second day - - -	= 39·2	39·9
Third „ - - -	= 39·8	40·3*
Fourth „ - - -	= 39·8	Found dead.
Fifth „ - - -	= 40·3	
Sixth „ - - -	= 40	
Seventh „ - - -	= 39	
Eighth „ - - -	Recovered.	

The animal which recovered has since been re-inoculated with anthrax, and, although in both instances the control animal succumbed to the disease, it has hitherto remained in good condition.

with subsequent insusceptibility.

The last re-inoculation was made over four months after the primary.

On the 28th of December a rabbit, weighing 2,250 grms., which had received ·01025 grms. of corrosive sublimate in all since the 1st of the month, was inoculated with fresh blood derived from a guinea-pig which had died of spore inoculation the same day.

The temperature record is as follows :—

Dec. 29th.	30th.	31st.	Jan. 1st.	2nd.	3rd.	4th.	5th.
39°·9	39°·6 Animal very lethargic. Swelling of inf. gland on side of inoculation.	40°·2 Rabbit torpid.	39°·4 Animal more lively.	39°·1	39°·5	40°	39°·4

On the 30th and 31st December and 1st of January the blood of the animal was carefully examined, and on each of the two latter days a guinea-pig was inoculated from it. In not one of the specimens of blood from the rabbit was I able to demonstrate the presence of anthrax bacilli, though an unusual number of the blood plates of bizoero were found to be present. The temperature of the guinea-pigs was practically unaffected. Like the rabbit, all these guinea-pigs survived, but whereas on re-inoculation the latter succumbed to anthrax, the rabbit escaped, and is still living.

Nature of influence on blood.

I may state that as far as my experiments have gone, no blood taken after inoculation from a medicated animal which was destined to survive subsequent inoculation of anthrax has proved fatal to other and unprotected animals (rabbits and guinea-pigs) inoculated from it.

The case is otherwise in animals which have received a dose of sublimate sufficient only to delay the fatal issue of the disease. In proof of this I quote the following :—

(*b*) Postponed death from anthrax.

A rabbit of 1·250 grms. weight had received ·00625 sublimate in the course of nine days. It was then inoculated from the blood of a guinea-pig just dead of the disease.

48 hours.	72 hours.	96 hours.	108 hours.
Temp. 39°·4. Animal dull and stupid. No bacilli in blood taken from ear. Inoculated guinea-pig. Guinea-pig survived.	Temp. 39°·6. No bacilli found in blood. Inoculated guinea-pig, which survived.	Temp. 40°·8. Is very apathetic, slight swelling in right groin, does not run. One bacillus found in many fields of microscope preparation taken from blood. Inoculated guinea-pig, which died in 44 hours of anthrax.	Temp. 35° C. Animal died. Only two bacilli seen in several specimens of heart's blood. Inoculation of blood caused death of guinea-pig within 48 hours.

Nature of influence on blood.

* The usual fall is not shown as the last temperature was taken the morning preceding the night during which death occurred.

In this case there was only a very slight multiplication of the bacilli within the body of the rabbit, but the blood inoculated into other animals caused their death within the usual time; large numbers of the micro-organisms being present.

We may conjecture in regard of animals which have undergone mercurial drugging preparatory to inoculation with anthrax, that multiplication in their bodies of the inoculated baccilli takes place to a very limited extent only. Hence we are not justified in assuming that the blood of a given medicated animal does not, 24 hours after anthrax inoculation, contain any bacilli, merely because transference of such blood into other susceptible animals fails to produce in them anthrax; for, obviously, when (relatively to the total blood) the number of bacilli circulating in an animal is small, it is probable that many samples of its blood may be taken none of which will contain any bacilli.

I am engaged at present in seeking for further information on the important questions which have arisen in the course of this research.

No. 6.

Reports on the Growth in Vacuo, and on the Thermal Death-point of Bacillus Anthracis; by J. P. Laws, F.C.S.

On the Growth of Bacillus anthracis in vacuo.

Inasmuch as the conditions of growth of bacillus anthracis in the animal organism and in test tubes plugged with cotton wool and open to the air, involve in both cases the presence of small and variable quantities of oxygen, it was deemed advisable to study by a series of experiments the effect produced on their growth by the most perfect moist vacuum that can be obtained.

Method.

For this purpose, cultivations were made in tubes which had been subjected to a most perfect exhaustion. The method of effecting this exhaustion was briefly as follows: culture tubes, 1 inch in diameter and 9 inches long, prepared from soft glass tubing, were sterilised in the usual way by exposure to a high temperature; after plugging with sterile cotton wool they were charged with sterilised peptone solution, the peptone solution being again boiled twice before the tubes were placed in the warm chamber to test their sterility. Immediately before inoculation each tube was again boiled three or four times at short intervals, in order to expel, as far as possible, all dissolved gases; they were then rapidly cooled and inoculated from a fresh culture. The open end of the tube was then drawn out and welded on to a fine tube in direct communication with a 5-fall Gimmingham mercurial pump.

This pump produces a rapid, and at the same time a far more perfect, vacuum than has been hitherto obtained with an ordinary Sprengel pump.

The exhaustion was continued for at least 30 minutes after the characteristic clicking sound was heard, and until the difference between the readings of the two barometers corresponded in each case satisfactorily with the tension of aqueous vapour for the particular temperature of the liquid at the time of experiment.

As there might possibly have been traces of dissolved gas remaining, the tubes were, in several cases, left in communication with the pump for prolonged periods before sealing; but, even where this was continued for $2\frac{1}{2}$ days, there was no change noticed at any time beyond the variation in the volume of the water vapour due to the variation of temperature.

In every single instance the result has been positive,—neither long continued working of the pump nor long communication with the vacuum influenced the final result.

Forty-three separate exhaustions, in all, were made, and the following are the chief features of interest.

Bacilli grown in vacuo.

Many of the bacilli show a marked change in form and appearance, the rods become much broader in the centre, and taper towards the end. At the broadest part they are about twice the breadth of bacilli in a normal culture. The protoplasm also becomes granular.

The altered bacilli when transplanted and placed under ordinary conditions assume their normal appearance in the same way as do those grown at 44·5° C. The variation appears to be due to the altered conditions entirely; and so soon as the abnormal conditions are removed the bacilli at once revert to their normal microscopic appearance.

So far as I have been able to observe, prolonged incubation of cultivations in vacuo does not lead to the formation of spores, but the organism becomes more granular in appearance, rapidly degenerates, and dies out in the course of from 10 to 20 days.

A series of experiments was made for the purpose of determining whether bacilli grown in vacuo possessed the same power of resisting disinfectants as ordinary bacilli. As in previous experiments, solution of

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On the Growth of Bacillus Anthracis in vacuo by J. P. Laws, F.C.S.

phenylpropionic acid was used for this purpose. The same method of determination was used as in the experiments on sulphuric acid, &c.

Bacilli grown in vacuo after inoculation from an ordinary culture for brevity sake will be spoken of as first generation vacuum bacilli. Similarly bacilli grown in vacuo, after inoculation with bacilli themselves grown in vacuo, will be called second generation vacuum bacilli, and so on to the third and fourth generations.

Experiments with peptone phenylpropionic acid :—

Solution 1 in 1,000.

Four experiments with first generation vacuum bacilli.
Two „ „ second „ „ „
Two „ „ third „ „ „

Peptone phenylpropionic acid solution 1 in 800.

Two experiments with first generation vacuum bacilli.
Two „ „ second „ „ „

Peptone phenylpropionic acid solution 1 in 600.

Two experiments with first generation vacuum bacilli.
Two „ „ second „ „ „
Two „ „ third „ „ „

Peptone phenylpropionic acid solution 1 in 500.

Three experiments with third generation vacuum bacilli.
One „ „ fourth „ „ „

In all of these experiments the resisting power of the bacilli to phenylpropionic acid coincided exactly with that of normal bacilli, and not, as might have been expected, with that of blood bacilli. In other experiments* the cultures were tested physiologically. So far as the experiments have been prosecuted it has been found that the cultures are inactive.

On the Thermal Death-point of Bacillus anthracis.

On Experiments on the Thermal Death-point of Bacillus Anthracis ; by J. P. Laws, F.C.S.

The following experiments have been made in order to determine in a precise manner the thermal death-point of Bacillus anthracis.

Method of maintaining a constant temperature.

The most convenient and most satisfactory mode is the following : The apparatus consists of a warm chamber furnished with a Page's Mercury Gas Regulator, and a long chimney ; enclosed in an external case of woodwork covered on the outside with thick baize. Free access to the glass front of the warm-chamber was gained by means of a door in the wooden case. The wooden case in turn was enclosed in a glass case much larger than itself, in order to prevent currents of air. The results obtained by this method are extremely satisfactory as regards the constancy of the temperature, the range of variation rarely exceeding more than 0·5 of a degree. In one case it amounted to 0·8 degree, during an experiment lasting four days.

The experimental tubes were freely suspended in the warm chamber by means of hooks, so as not to allow them to come into proximity with any surface of the metal.

The thermometer was suspended in the chamber in the same way as the experimental tubes : the readings of the thermometer, therefore, expressed the temperature to which the tubes were subjected.

The general methods of culture were precisely similar to those described in my previous report to the Board (*see* experiments on sulphuric acid). Bacilli used for inoculation were exclusively sporeless growths, and were obtained by the method previously described, viz., transplanting at frequent intervals.

* The nature and circumstances of the test experiments are not reported. It will have been observed that Mr. Laws was operating with bacilli grown in a fluid medium.—G. B.

In the following tables I have arranged the various experiments in the order of temperature, and appended to each experiment the final result.

Temperature of Incubator.	Number of Experiment.	Number of Tubes in Experiment.	Result of Experiment and Remarks.
41·5° C.	1	3	All fertile and normal in appearance.
42° C.	2	6	All fertile and normal.
,,	3	6	All fertile and normal. A slight delay in the growth.
43° C.	4	3	Two out of three proved fertile. Growth slightly altered.
,,	5	4	Three out of four proved fertile.
,,	6	6	All fertile; spores appeared at a very early stage.
,,	7	5	All fertile. As the filaments are much thinner the spores are more marked in appearance.
44° C.	8	5	Three out of five fertile.
,,	9	5	Four ,, ,,
,,	10	5	Four ,, ,, In one of the four fertile tubes the growth was very small.
,,	11	5	All fertile; two considerably retarded.
,,	12	5	All fertile, but the crop was very small in four out of five cases. In all the above growths the appearance of the bacilli is markedly changed. The filaments are very thin and spores make their appearance at an early stage.
44·3° C.	13	5	No growth occurred. This may be accounted for as the temperature of the incubator was at 44·9 most of the time.
,,	14	5	Three out of the five fertile.
,,	15	5	,, ,, ,,
,,	16	5	All fertile.
,,	17	6	Four out of six fertile.
,,	18	6	All fertile. In all the above cases the growth was changed. The naked eye and microscopical appearances being quite altered (*see* general statement).
45° C.	19	6	In all these four experiments no growth occurred in any case and the tubes were found to be permanently sterile, as no growth occurred after they were transferred to 35° C.
,,	20	6	
,,	21	5	
,,	22	5	
,,	23	5	One out of the five germinated, but in this experiment the temperature of the incubator fell to 44·5°.
45·5°	24	5	In all these experiments no growth occurred in any single instance.
,,	25	5	
,,	26	5	The bacilli were proved to be incapable of further development, for by placing the tubes at 35° C. still no growth occurred.

Summary.—No difference could be detected in the growth of the bacilli until the temperature was 43° C. A change then became apparent, and at the higher temperatures was more pronounced, until at 45° C. no growth occurred. This temperature (45° C.) did not merely exert a restraining influence on the bacilli when exposed to it for 24 hours, but permanently destroyed their vitality and power of germination when afterwards placed under favourable conditions.

With regard to the fertile crops of bacilli grown at the temperatures intermediate between 43° and 45° C., two points in particular were observed:—1st. The bacilli become thinner, and more frequently grow in a meshwork of filaments; 2ndly. Spore formation takes place at a much earlier stage than in the normal culture.

If any of the abnormal growths are transplanted and kept under favourable conditions, the bacilli at once assume their ordinary normal form. A fertile growth in experiment No. 15 was tested physiologically. A slight disturbance was caused after four days, which soon passed off; at present the inoculation has not been repeated with a normal culture.

In a second test experiment of the same kind, the growth proved inactive.*

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* Mr. Laws' researches were brought to a conclusion in the summer of 1885; and his report is necessarily incomplete. Also, details as to the phenomena of the early "spore" formation are wanting; and he does not mention the source of the anthrax bacilli used in his inoculation of solutions, nor the time that elapsed before the physiological testing of the bacilli from exp. 15.

With some samples of cultures grown at 44·5° C. by Mr. Laws and given by him to Dr. Klein, it was found possible to start series of sub-cultures, both in liquid and in solid media. The bacilli of these series, however, had different microscopical characters from those of bacilli anthracis, and they proved to be incapable of producing any disease in animals.—G. B.

No. 7.

Report on the Disinfectant Properties of Oxygen and Ozone. —By J. Theodore Cash, M.D.

App. B. No.

On the Disinfectant Properties of certain Gases; by J. Theodore Cash, M.D.

The desirability of examining the effect of various gases upon the growth of micro-organisms, has attracted the attention of numerous observers who have experimented with the object of ascertaining how far growth might be accelerated, retarded, or suspended, by subjecting cultivations of certain species of septic or pathogenic organisms to various medicated atmospheres.

Thus, amongst others, Grossmann and Mayerhausen* have examined the action of oxygen, hydrogen, carbonic acid, and ozone upon septic micro-organisms. Spilman† repeated these experiments with the difference that he employed a pathogenic micro-organism (anthrax bacillus). Braidwood and Vacher‡ exposed vaccine lymph to the action of oxygen, ozone, carbonic acid gas, &c. Quite recently McKendrick and Coleman§ have carefully examined, by means of more exact methods, the destructive action of ozone upon putrefactive germs.

As the results obtained by these English and German observers seemed to be to some extent discrepant, and as the range of the inquiry seemed capable of useful extension, the following experiments which deal with the action of oxygen and ozone were undertaken by the direction of the Board.

Oxygen.

Oxygen.

The observation of Grossmann and Mayerhausen that *oxygen* in its action upon putrefactive micro-organisms caused a heightened vitality as evidenced by their increased movement and multiplication by fission was confirmed by Spilman with regard to anthrax. His method of examination was to carry a current of oxygen through a Recklinghausen's chamber into which a drop of fluid containing anthrax bacilli had been introduced, and to watch with a high power of the microscope (Zeiss E. OC. 4.) the changes which occurred.

Although this observation pointed to an active growth of the bacillus, it seemed advisable to test carefully whether the anthrax virus retained its full degree of potency, or whether it became in any sensible degree enfeebled as a result of extra-abundant oxidation.

The mode of experimentation I adopted will now be briefly described.

Purity of gas.

As purity of the gas to be employed was, of course, essential, I adopted means for removing traces of chlorine which might come over in the process of decomposing chlorate of potassium by heat in presence of peroxide of manganese.

With this object the oxygen escaping from the iron retort in which decomposition took place was passed at once through a solution of slaked lime, and thereafter through 3 V tubes containing pumice stone moistened with caustic potash in order that all carbonic acid gas might also be removed from it. As an additional precaution the gas holder employed for the purpose was usually charged the day before use so

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* Pflüger's Archiv., Bd. XV.
† Zeitschr. für Phys. Chemie., Bd. IV.
‡ Contribution to life-history of Contagium, Brit. Med. Jnl., 1882.
§ Communication to Brit. Assoc., 1885.

that complete purification might be effected by means of the layer of water at the bottom. From this gasometer, which had a capacity of 7,000 C.C., a smaller Pepy's gasometer was filled, and from this the discharge of gas occurred under the pressure of the column of water kept at a constant level contained in the open receiver at the top of the apparatus.

In the oxygen experiments I employed as a discharge tube a fine glass tube with a long neck and a bulbous extremity, which was pierced with numerous fine apertures for the escape of the gas. After this discharge tube had been purified by boiling water, its bulbous end was passed to the bottom of the test tube containing anthrax cultivation upon which it was desired to act, and plugs of sterilised wool in the orifice of the test tube were carefully adjusted around, in order that contamination from the surrounding air might be avoided.

The system of glass and india-rubber tubes connecting the discharging gasometer and the cannula were in like manner purified by boiling water and then rapidly adjusted. The rate of discharge was regulated by a turncock on the upper part of the cylinder of the gasometer, and further by a screw clamp with which the india-rubber tubing could be compressed. The level of the water in the pressure cylinder was maintained throughout the experiment.

Avoidance of spore formation.

It must be remembered that the constant agitation by the stream of oxygen of the fluid in which the growth of anthrax bacilli was present, would favour spore formation by tending to bring bacilli up to the surface; but on the other hand continued movement is altogether unfavourable to production of spores. If, however, the bacilli were washed up on to the side of the glass by the expanding bubbles and remained there, a spore production in such bacilli in the course of five or six hours might possibly occur. It was therefore deemed prudent usually to accomplish each experiment within less time than would be required for this transformation. In the ensuing experiments I shall give the time at which the gas circulation was commenced and terminated, as well as the amount of gas discharged at a uniform rate during the interval.

Changes induced in anthrax.

In order to test the changes induced in an anthrax cultivation during oxygenation, inoculations of animals were made in the course of the experiment, one inoculation occurring with the original cultivation or mixture to serve as a control or contrast to the rest.

Inoculations were either made as soon as a certain quantity of gas had been circulated, or a fine bulbous pipette was charged from the culture, its ends closed, and inoculation performed with the reserved samples at the end of the experiment.

I proceed to quote certain experiments selected from the total number performed.

(1.) Fresh anthrax blood recently introduced into a sterile nutrient fluid.

(2.) Cultivation at ordinary temperature of some days standing of anthrax in nutrient fluid.

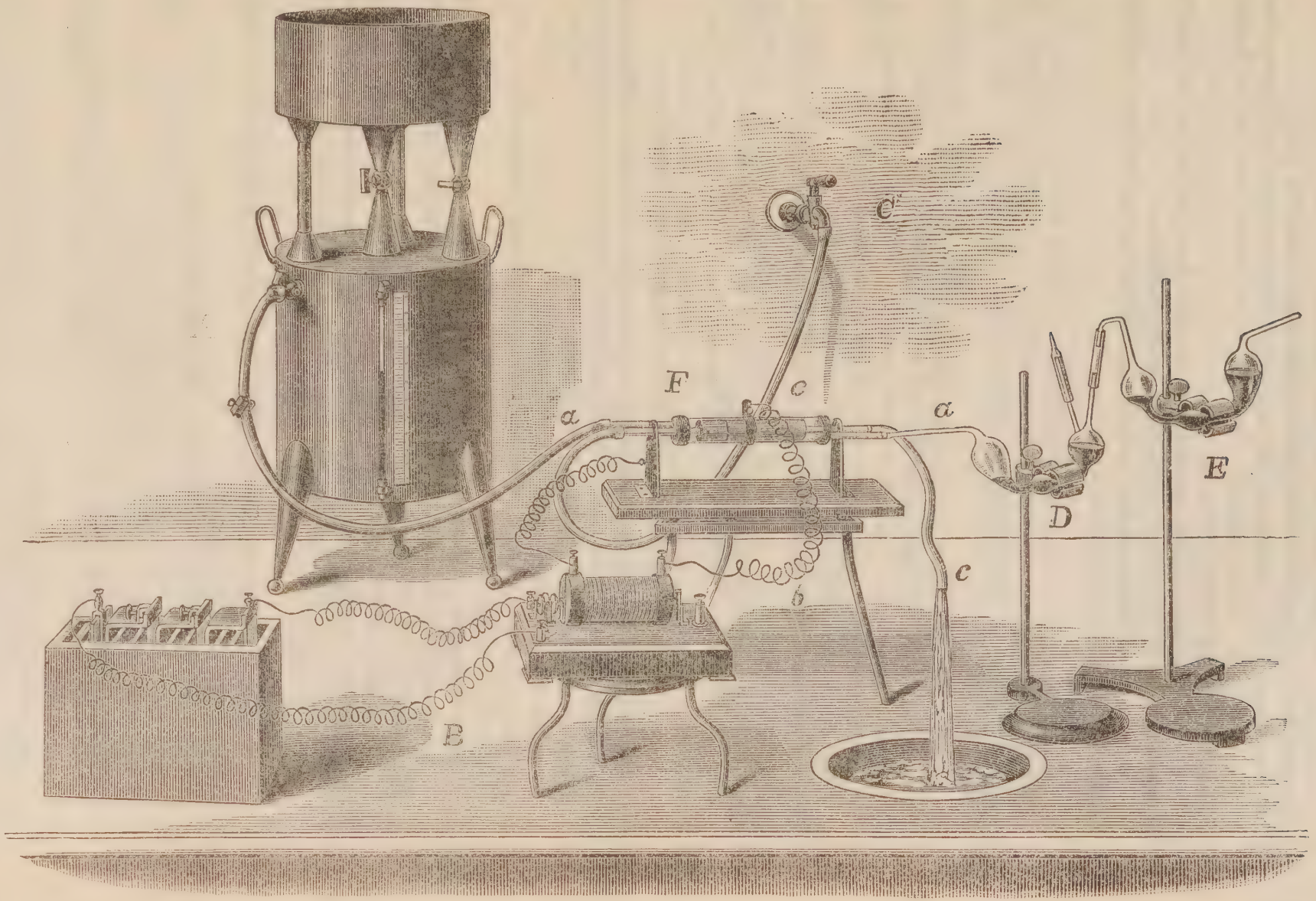
(3.) Fresh anthrax blood recently introduced into normal saline solution.

(4.) Anthrax previously grown for 48 hours at high temperatures.

1. *Blood Bacilli.*

Experiment A.—Take half a drop of blood from the heart of a guinea-pig just dead of anthrax (after 40 hours from a cultivation of anthrax spores in beef broth) and transfer to a test tube containing 8 C.C. of sterile slightly alkaline beef broth.

DIAGRAM OF APPARATUS EMPLOYED IN THE OXYGEN AND OZONE EXPERIMENTS.



Aa. Gasometer and tubes for gas conduction. *Bb.* Electrical coil, Groves' elements, and connections.
Cc. Water tap and tubes. *D.* Special nitrogen bulb for infusion or cultivation with two vertical arms.
E. Nitrogen bulb for iodide of potash solution. *F.* Ozone generator.

12 o'clock.—Reserve sample A.a. Commence circulating oxygen through the cannula from the gasometer at the rate of 2,500 C.C. per hour.

5 o'clock.—13,000 C.C. of oxygen have passed through the test tube; sample A.b. Inoculate two guinea-pigs with A.a. and A.b.

On examining contents of the test tube a few bacilli (2 or 3) are present in each field. They appear unaltered and stain well with Spiller's purple. No spores present.

After 24 hours.—Both animals A a. and A.b. show an œdematous swelling in the groin above the seat of inoculation..

48 hours.—Both animals are dead. Show great œdema, and their blood is crowded with bacilli.

Experiment B.—Transfer half a drop of blood from the heart of an anthrax guinea-pig (40 hours from cultivation of bacilli), which died in the course of the previous night, into a tube of 9 C.C. beef broth (slightly alkaline).

10.45 o'clock.—Shake tube; inoculate guinea-pig B.a. and commence passing oxygen through mixture at a rate of 2,000 C.C. per hour.

2.40.—8,000 C.C. of oxygen have passed. Inoculate guinea-pig B.b.

Examination of contents of tube showed about 4 bacilli to each field. The bacilli appeared healthy. No spores present.

24 hours.—Both guinea-pigs show considerable and equal swelling in the right groin.

48 hours.—Both animals dead. Extent of rigor equal. The blood of each abounds with anthrax bacilli.

2. *Established Cultivation of Anthrax Bacilli.*

Experiment C.—Take tube of beef broth inoculated with anthrax blood three days previously. The growth is pure and abundant at the bottom of the tube. No spore formation.

12.30 o'clock.—Inoculate guinea-pig C.a.

Commence circulation of oxygen through the cultivation at 2,800 C.C. per hour.

3.0.—7,000 C.C. of oxygen have passed. Inoculate guinea-pig C.b.

5.30.—14,000 C.C. in all have passed. Inoculate guinea-pig C.c. The bacilli still stain well with Spiller's purple.

48 hours.—All three guinea-pigs are dead. C.a. and C.c. in rigor. C.b. not yet in rigor, and had therefore died subsequently to the other two. All presented the evidences of death from an active anthrax virus.

Experiment D.—A cultivation of anthrax in 7 C.C. beef broth faintly alkaline of six days' growth.

The growth is very abundant. No spores present.

11.30 o'clock.—Inoculate guinea-pig D.a. from cultivation. Commence circulation of oxygen 7,000 C.C. per hour.

1.30.—14,000 C.C. have been rapidly circulated.

3 o'clock.—In all 21,000 C.C. of oxygen have passed through the cultivation.

Inoculate guinea-pig D.b.

On examination of tube a few moving bacilli, apparently B. subtilis, which have found their way into the cultivation during the removal and readjustment of the plug of cotton wool in the mouth of the tube, are found to be present amongst the anthrax rods which are broad and large, and appear more numerous than in the original cultivation.

48 hours.—Both animals dead of anthrax.

3. *Fresh Anthrax Blood introduced into Tubes containing Normal (0·75 per cent.) Salt Solution. (This solution is neither nutrient nor actively antagonistic to the life of the Bacillus.)*

Experiment E.—Take half the spleen of a guinea-pig which has died within 48 hours of its inoculation with anthrax spores, and pound it up well in 30 C.C. of 0·75 per cent. salt solution. Of this put 7 C.C. into a sterile tube.

10.55 o'clock.—From this infusion inoculate a guinea-pig E.a.

11.55.—3,500 C.C. of oxygen have passed. Inoculate guinea-pig E.b.

12.25.—Passed very rapidly 5,400 C.C. more (8,900 in all), of oxygen. (Speed so great that some of contained fluid was driven up to plug of wool, soaking this, and escaping to a small extent.)

Inoculate guinea-pig E.c. (Bacilli in remaining fluid healthy. No spores present.)

48 hours.—All three guinea-pigs dead. Each with great subcutaneous œdema of the abdomen. The blood of all three crowded with bacilli. No difference could be detected.

A guinea-pig inoculated with the blood of E.c. died within 48 hours.

4. *Anthrax grown at High Temperatures.*

Experiment F.—Take a tube of faintly alkaline beef broth inoculated 48 hours previously with anthrax blood and kept thereafter at a constant temperature of 43° C. Many of the bacilli are contorted and dead, others do not appear abnormal and still stain well.

9 o'clock.—Inoculate guinea-pig F.a. from the culture and circulate oxygen slowly (at the rate of 1,071 C.C. per hour).

4 o'clock.—7,500 C.C. passed. Inoculate F.b. from the culture which is found to contain distinctly living bacilli, though as before many "corpses" of bacilli are also present.

40 hours.—F.b. died of typical anthrax.

46 hours.—F.a. died of typical anthrax.

Conclusion as to influence of oxygen.

I have quoted under the enumerated headings 1, 2, 3, 4, a number of experiments intended to show the effect of oxygen in mitigating the activity of anthrax virus, when it was used upon healthy bacilli in circumstances favourable (1 and 2) and somewhat unfavourable (3) to growth, and also (4) upon bacilli probably weakened in their activity to some extent by the high temperature at which they had been grown. *In every case the result was simply negative.* No mitigation of the activity of the anthrax virus was produced by oxygen, though I have carried the circulation in six hours up to over 40,000 C.C.

As regards the occurrence of an earlier spore formation in oxygen than results from exposure of anthrax bacilli in atmospheric air, no positive evidence has been obtained, but the form of experiment was not favourable to determination of this point, as the element of motion in the culture introduces a modifying influence with which reckoning must be made.

No destruction of bacilli as a result of the action of oxygen has been observed, and from repeated examination of the solutions during the process of gas circulation, I can in general terms confirm the observations of the authors already referred to, that a considerable increase in multiplication of the bacilli was produced—sometimes much greater than would have occurred at the same temperature in the same medium and in an equal time in a normal cultivation.

Ozone.

I will now proceed to experiments in which ozone has been employed as a possible disinfectant, and will preface the record of experiments by a few statements with regard to the observations of others on this subject.

Binz has examined the action of this gas upon man, several other mammals, and lower vertebra. He finds that its chief action is that of a soporific even in small quantities; in larger quantities its irritant action upon the respiratory passages and the lungs becomes more prominent, inducing hæmoptysis and active bronchial catarrh.

Outside the animal body its action upon albumen is remarkable, and evidences a profound change in the physical properties of this substance, which may have an important signification in the present connexion.

I quote from Dr. Brunton :—*

"Albumen undergoes an extraordinary change in consequence of the action of ozone, and becomes after exposure to it uncoagulable by boiling and by acids excepting in large quantities, and by metallic salts, with the exception of basic acetate of lead and of alcohol. The action of alkaloids upon this ozonised albumen is even more remarkable than upon ordinary albumen, for when mixed with it in small quantity they restore its coagulability to the albumen, and cause it to coagulate far under the boiling point." * * * *

With regard to its action upon bacteria, the two most interesting experiments to us in the present connexion are those of Spillmann, of Grossmann with Mayerhausen, and McKendrick with Coleman.

The first-named observer studied the effect of passing a current of various gases through a chamber placed on the stage of the microscope, and kept at a given temperature, into which a drop of fluid containing anthrax bacilli had been introduced; the changes in growth, spore formation, &c., were thus observed. His results, reduced to few words, are that the anthrax bacillus is in no way affected by ozone, and thus differs notably from septic micro-organisms. In order to test the retention of activity of the virus, he circulated an undetermined but evidently large quantity of ozone through 2 C.C. of anthrax blood for seven hours, and found that an animal inoculated therewith died within 48 hours of anthrax. In marked contrast is his observation that in 20′ to 30′ circulation of ozone all putrefactive bacilli were destroyed. Grossmann and Mayerhausen, who have already been referred to as investigating the action of oxygen upon putrefactive bacteria, also extended their observations to ozone, and found that this gas arrested movement and development of these micro-organisms in all their stages. The changes were rapid, and when the gas had reached a sufficient concentration, almost instantaneous. McKendrick and Coleman have instituted a large number of experiments upon the destruction of putrefactive organisms by subjecting them to the action of ozone in known quantities. (Professor McKendrick has kindly favoured me with the notes of a number of the experiments, some of which formed the subject of a paper read by him at the meeting of the British Medical Association, at Aberdeen, in 1885.)

McKendrick and Coleman found that ozonised air was antiseptic, if not to the extent they had anticipated. By placing a small ozoniser in the interior of a bottle containing air or oxygen, and also containing gelatine or other putrescible material, and then ozonising by means of powerful induction currents, they found putrefaction was markedly

* Brunton; Pharmacology and Therapeutics, p. 44.

delayed. In their reported researches ozone was found to be fatal to existing bacteria, but to be powerless as regarded spores. Putrefaction was delayed many days by saturating a nutritive medium (bouillon) with ozone.

The plan of experiment which I have followed differs but slightly from the McKendrick-Coleman method. The discharge of oxygen (from which I always produced ozone) took place from the small Pepy's gasometer already referred to, holding 7,000 C.C., the gauge of which was carefully graduated. Conversion of ozone was effected by passing the oxygen slowly through a Siemen's ozone generator (manufactured by Tisley) which stood in connexion with a Ruhmkoff's coil, worked by two or three Grove's elements. (The silent discharge from the foil plates of the Tisley's tube was found when coil "a" was used to effect only a small conversion of the oxygen into ozone; coil "b" was much more powerful.) As it is essential that no india-rubber tubing be used in the apparatus, on account of the rapidity with which ozone acts upon it, the gas issuing from the generator was passed directly into the horizontal arm of a modified nitrogen bulb which held the infusion or transferred cultivation of the organism upon which it was desired to act, and which was connected with the ozone generator by means of a paraffin joint. The spherical bulb I had specially constructed with two vertical arms, slightly diverging from one another; one of these served to connect the bulb with a second bulb containing acidulated iodide of potassium solution, whilst the other was kept closed by means of a glass cap secured with paraffin, and removed only when it was desired to obtain a sample of the contained fluid, or to test its reaction. This removal could be accomplished without disturbing the rest of the apparatus. The joint between the two bulbs was secured by means of paraffin.

An estimation of the total iodine liberated from iodide of potassium in the second or distal bulb was obtained by subsequently titrating the solution with hyposulphite of sodium (centinormal solution) in presence of a little freshly-prepared starch paste. (The strength of the hyposulphite solution was frequently controlled by means of a standard solution of iodine.) This of course would not serve as a gauge of the total ozone generated; if the bulb containing the cultivation or infusion intervened, it showed merely the amount of ozone passing unchanged through the latter.

With the object of determining the total conversion after the experiment was completed, a known quantity of the gas was passed directly and at the original speed of discharge, for half an hour, into a nitrogen bulb containing iodide of potassium. The total conversion for the entire experiment was of course easily calculated.

By subtracting the amount of ozone escaping unchanged from the total ozone generated, the proportion of the gas disappearing in its transit through the cultivation bulb was arrived at.

This escape of ozone through the cultivation may arise from two causes: 1, because the bubbles of gas may not be in sufficiently prolonged or intimate contact with the fluid contained in the bulb, in which case the ozone is only partially absorbed; and, 2, because the cultivation may have lost its power of absorbing or reducing the ozone.

In the nitrogen bulb, however, the process of exposure is well maintained, first as the gas presses on the surface of the fluid, then as it passes to the central enlargement and then finally goes over into the spherical bulb.

If two bulbs are employed in series, each containing iodide of potassium solution, it will be found even when the generation of ozone is large and the discharge moderately rapid, that a considerable liberation of iodine occurs in the proximal bulb, but that the second bulb remains absolutely free from colour, thus indicating that no ozone has penetrated to it.

The only inconstant element in the calculation is that of the weakening of the elements which would cause a diminution in conversion of a given quantity of oxygen; but in the length of time taken by an experiment, this change was found, by estimating the ozone generated before and after the actual experiment, to be so slight, that the variation may practically be disregarded. The most favourable speed of discharge of oxygen through the ozone generator I found to be about 500 C.C. per hour. This was roughly equal to the passage of 10 small bubbles per minute through the solution.

From a large number of experiments I shall select a few dealing with the destruction of anthrax bacilli (from fresh blood and cultivations), bovine tuberculosis, and human tuberculosis.

Anthrax.

Experiment G.—From the blood of a guinea-pig which had died within 44 hours after inoculation of anthrax bacilli, tubes of beef broth with peptone were inoculated and kept at room temperature (18° C.) On the fifth day of growth one of the tubes was selected, and on examination was found to be a pure cultivation of anthrax well grown.

A sample of this was reserved after the tube had been shaken in a sealed pipette. The rest (about 10 C.C.) was placed in the nitrogen bulb (3 Grove's coil (a), Tisley's ozone generator). 0h., experiment commenced; 105′, first sample of ozonised cultivation taken; 225′, second sample taken.

The production of ozone was feeble in this case, as in all in which coil (a) was used; no more than ·00020 grm. of ozone was estimated to have been generated in the entire experiment.

At 4 p.m. three guinea-pigs were inoculated—

1.	Control - - - - -		G.a.
2.	Sample ozonised cultivation -	105′	G.b.
3.	„ „ „ - -	225′	G.c.

24h.—All three animals show some enlargement of groin on the right side (seat of inoculation), that of G.a. being most pronounced.

48h.—G.a., G.b., and G.c. all dead in the course of last night; not any of them surviving more than 40 hours after inoculation.

Examination of the blood and organs did not reveal any material difference in the three animals, nor from the course of the induced disease was any to be anticipated.

Experiment H.—Two drops of the blood of a guinea-pig dead in 40 hours after inoculation with anthrax bacilli, placed in a tube of beef broth, and forthwith subjected to experiment without interval being allowed for growth and multiplication of bacilli.

Control sample reserved in sealed pipette.

3. Grove's coil (*a*), Tisley's generator. The coil went indifferently.

0h. 0m. Commenced circulation of oxygen through the ozone generator.

2h. 45′.—First sample taken.
4h. 45′.—Second „ „
5h. 10′.—Inoculated. H.a., guinea-pig (control). H.b., guinea-pig (1st ozone). H.c., guinea-pig (2nd ozone).

Inoculation was made of as nearly equal quantities of the several samples as possible.

The total ozone generated was from ·001–·002 grm., but on account of some irregularity in discharge of the gas exact estimation was not possible.

24h.—H.a. already shows subcutaneous œdema of the right groin. The others do not show any marked swelling.

48h.—H.a. dead; blood crowded with bacilli. H.b. and H.c. both show some groin swelling, H.b. being the more extensive.

72h.—H.b. dead. Bacilli in blood not very numerous.

96h.—H.c. dead.

(A guinea-pig inoculated with the blood of H.c. died within two days.)

In this retardation there is, therefore, some suggestion of a reduction of the virulency of the animal poison inoculated; but retardation of the anthrax disease was not productive of a virus in anywise weakened in its activity with regard to other animals.

So far I have recorded results in which, although the experiments extended over a considerable time, only very small quantities of ozone were produced. Houzean (Comptes Rendus, Vol. LXII., p. 1286) states "that the production of ozone is 8 times greater for any volume of "oxygen than the same volume of air, both being electrically acted upon." McRendrick and Coleman, who used atmospheric air for the production of ozone, and who passed only 100–200 C.C. of air per hour through the ozone generator, found that no less than ·0068 grm. of iodine was liberated from the iodide of potassium solution in the course of an hour. This is in excess of the production at which I have arrived, although I am aware that their apparatus was more powerful than that which I employed.

It is open to question whether some of the iodine in air experiments may be liberated by bodies other than ozone present in the air. In control experiments which I have instituted with the view of determining the relative production of ozone as indicated by the decomposition of fresh iodide of potassium solution in presence of a trace (·5 C.C. $\frac{n}{10}$) of sulphuric acid, I have found, all other conditions being equal, that almost 5 times as much ozone was obtained from the passage of oxygen as from the passage of atmospheric air.

Thus, the colour was discharged from 10 C.C. of potassium iodide solution through which ozonised oxygen had been passed by 6·6 C.C. of $\frac{n}{100}$ (centinormal) hyposulphite of soda solution (equal to ·001584 grm. of ozone) colour discharged, all other conditions being the same, but air employed 1·5 C.C. $\frac{n}{100}$ hyposulphite solution.

Experiment I.—Take a cultivation of anthrax of 4 days standing in beef broth derived from blood of guinea-pig. Growth of bacilli very abundant. A sample of this was sealed in a sterilised pipette. (Two Grove's; new coil (*b*) giving a $\frac{1}{3}$-inch spark. Tisley's form of Siemen's generator.)

12.30 o'clock.—Discharge of oxygen commenced.
1.15.—1st sample taken.
2.55.—2nd „
Ozone generated before 1st sample taken ·003 grm.
Total ozone before second sample ·0098 grm.

At 3.15, inoculate with I_a 1st guinea-pig control sample. I_b 2nd guinea-pig with 1st ozone. I_c 3rd guinea-pig with 2nd ozone.

In 40 hours control guinea-pig dead, blood full of anthrax.

No sign of swelling in I_b and I_c.

Both of these animals survived and showed no indisposition.

Experiment K.—The next experiment which I shall quote illustrates the complete series one desires to demonstrate in testing the modifying influence of ozone upon pathogenic bacilli; viz.—The gradual weakening of the virus and its ultimate destruction.

One large drop of fresh anthrax blood (guinea-pig dead from bacilli in 40 hours) introduced into a nitrogen bulb containing 10 C.C. of sterile beef broth. After shaking, a sample of the mixture was reserved in a closed pipette,—(2 Grove's, coil (*b*) cultivation bulb and distal (iodide of potassium) bulb in situ).

12 o'clock.—Began circulation of ozone.

12.30.—Take sample 1 ozone.

1·10. „ „ 2 „

2·3. „ „ 3 „

2·40. „ „ 4 „

Shortly after the experiment was concluded, five animals were inoculated from the several samples, which had been taken in sealed tubes.

Day of Month.	(1.) K.a. Control.	(2.) K.b. 1st Ozone.	(3.) K.c. 2nd Ozone.	(4.) K.d. 3rd Ozone.	(5.) K.e. 4th Ozone.
13th	Distinct fulness of right groin.				
14th	Dead; blood full of anthrax.	Glandular enlargement.	Fulness in groin.	Dead; spleen much enlarged; blood containing a moderate number of bacilli.	
15th			Died in the evening; blood full of anthrax bacilli.		
16th		Died last night.			No swelling.
17th					Survived.

A break in the regularity of the series occurs with regard to the second animal K.b. which might have been expected to die as soon as No. 3. (K.c.)—but as it survived the latter only a few hours, the occurrence has probably no significance as such variations with ordinary virus occasionally occur. As regards the quantities (in grammes) of ozone generated in this experiment, I will from calculation give a series corresponding to the samples from which animals were inoculated.

1	2	3	4	5	Total
0	·000543	+ ·00063	+ ·00096	+ ·00053	·002663 grm.

We may for this experiment then represent the result thus, correction having been made for free iodine in the original potassium iodide solution—

Up to—·00118 grm., no mitigation.
„ ·00214 „ fatal issue delayed.
„ ·00267—destruction of virus.

The total ozone which passed the cultivation unchanged and which liberated iodine from its combination with potassium in the distal tube was ·000312 grm.

A guinea-pig inoculated from No. 2 died within 48 hours.

From the blood of animal No. 4, which died on the fifth day, a guinea-pig was inoculated which died in 48 hours.

Animal No. 5 is not immune from anthrax.

I regard it as having been inoculated with a fluid in which the virus had been practically destroyed. I have subsequently inoculated many animals which escaped as No. 5 did, and have not found in any of them any appreciable resistance to the normal virus.

Experiment L.—Four drops of heart's blood of a guinea-pig dead of anthrax 40 hours after inoculation of anthrax bacilli from cultivation, were introduced into 10 C.C. of slightly alkaline beef broth. The whole of the mixture which had a moderately deep red colour was transferred to the nitrogen bulb, and a sample was reserved for subsequent inoculation. (2 Grove's, coil b. (went all day without pause). Siemen's ozone generator. (Ten bubbles of oxygen pass per minute.)

12.16 o'clock.—Began circulation.

1.16.—Colour of hæmoglobin less bright, cultivation less translucent, iodide of potassium bulb slightly yellow. Reaction alkaline—·00288 grm. of ozone has passed.—Take Sample 1 ozone.

2.16.—Reaction faintly alkaline ·00576 grm. ozone passed.—Take Sample 2 ozone.

3.16.—Anthrax bulb looks soapy, still has very faint pink tinge. Much iodine liberated in distal bulb. Reaction slightly acid. ·00864 grm. ozone passed. Take Sample 3 ozone.

4.16.—·01152 grm. ozone passed. Solution strongly acid.—Take Sample 4 ozone.

5.16.—·0144 grm. ozone passed. Take Sample 5 ozone.

The strongly acid reaction did not disappear upon boiling. ·00432 grm. of ozone passed into the second bulb unchanged.

5.20.—Inoculated five guinea-pigs of nearly equal size.

Control	1st	2nd	3rd	4th	5th
After 48 hours:					
Dead, full of anthrax.	Decided fulness in the right groin.	No swelling.			Has large soft swelling in right inguinal region.
	All survived.				
After 72 hours:					Dead. Only 2 or 3 bacilli seen in many fields of both spleen and heart's blood. Inoculate guinea-pig with blood.
After 96 „					Animal dead. In 20 hours crowded with bacilli.

The anomalous result obtained here demands a little attention. The control animal died in 40 hours; the animal which was inoculated with blood which had been longest exposed to the action of ozone died on the third day, whilst all the intermediate animals survived. The amount inoculated was as nearly as possible identical in all cases. Dried cover-glass specimens made from the solution at different stages of ozonisation revealed the fact that the bacilli were not disintegrated or contorted, that they still stained moderately well, and that no spores were present. I am driven to conclude that in an unusual susceptibility which this animal (No. 5) showed to a virus which in a stronger form failed to affect other animals, the reason of the fatal result lies.

Dr. Klein has especially drawn attention to the fact that variations in susceptibility to anthrax may show themselves in guinea-pigs. Variation in power of resistance to alkaloids, which have in their action something in common with animal poisons, is a feature I have frequently seen exhibited by individual animals.

In this inoculation, bacilli were introduced in a state so enfeebled that they perished, or at any rate failed to multiply in certain animals into which they were introduced, and, so far as these animals were concerned, the bacilli were inoperative. The fifth animal offered some peculiarity which fostered their growth and virulence, and it perished in consequence.

In an experiment closely similar to the last, it was found that whilst all the animals inoculated with anthrax, through which ·005 grm. of ozone had passed, escaped, the control died in due course.

The bacilli still stained moderately well, but altogether refused to grow when introduced into beef broth.

Anthrax spores.—I have passed through spore cultivation quantities of ozone, varying up to nearly ·02 grm. without seeing any destruction or reduction of their virulency.

Tuberculosis.

(*a.*) *Human Tuberculosis.*

The length of time which must necessarily elapse between inoculation and the termination of the experiment is so considerable in this disease that I can only speak at present of the earlier symptoms shown in the majority of cases. The symptom which we usually accept as a guide is the enlargement of lymphatic glands above the seat of inoculation, and it is seldom that this indication of infection (especially when the swelling becomes hard) is found to be unreliable.

As the best mode of approaching the subject I will quote a few experiments in detail in order to show in how far ozone is active or the reverse in destroying a micro-organism which is known to possess a higher power of resistance than that of anthrax—at all events greater than that of anthrax in its bacillar form. It is impossible in the present state of our knowledge to assert that spores are entirely absent from any tubercular material in which the pathogenic bacillus is present.

Experiment M.—The sputum of a tubercular patient which was found to contain large numbers of Koch's bacilli was taken for this experiment. It was moderately free from septic micro-organisms. 2 C.C. of the sputum were well stirred with a little normal (·75°/₀) salt solution passed through a coarse filter and transferred to a nitrogen bulb. (2 Grove's, coil b. Weak acid employed. Oxygen passed

through ozone generator, through infusion of sputum, and finally through a bulb containing fresh acidulated solution of iodide of potassium. 500 C.C. circulated per hour.)

0h. 0m.—Commence circulation of feebly ozonised oxygen.

1h. 40m.—·0003372 grm. of ozone generated (1st sample).

2h. 40m.—·000558 „ „ (2nd „).

Total ozone liberating iodine in distal bulb=·000098 grm.

2h. 50m.—Inoculated guinea-pigs with (*a.*) Control infusion. (*b.*) First sample ozonised infusion. (*c.*) Second sample ozonised infusion.

In three days' time all three animals showed a distinct lymphatic swelling of the inguinal gland above the seat of inoculation, and the subsequent course of the disease was identical in all of them. One of the guinea-pigs killed on the twenty-fourth day after inoculation showed a distinctly tubercular spleen, but the lungs, liver, and kidneys were free of disease.

Experiment N.—An infusion of about two grammes of fresh tubercular human lung abounding in bacilli was made with sterilised beef broth and passed through a coarse filter. The resulting fluid was of a dark brown colour and somewhat turbid. Reserved sample of this in closed pipette for control inoculation. (2 Grove's, coil b. All paraffin joints in order. Discharge of oxygen 500 C.C. per hour).

0h. 0m.—Commence passage of gas through ozone generator and double bulbs.

1h. 30m.—·00072 grm. of ozone has been generated. First sample, ozonised infusion.

3h. 20m.—·001644 grm. of ozone in all generated. Second sample, ozonised infusion.

(The total ozone which passed unchanged through the infusion after allowing for liberation of iodine from of a similar solution exposed to air for an equal time was ·00026 grm. Therefore ·001384 grm. disappeared in the infusion.

3h. 23m.—Guinea-pigs were inoculated from the reserved and the ozonised samples of the lung infusion.

I cannot give full details of the subsequent course of this experiment, as all the animals inoculated are still alive. At the present moment, from the condition of their inguinal lymphatic glands it is safe to state that all of them are tubercular, but that the guinea-pigs inoculated with ozonised material were later in developing a hard inguinal swelling than the control animal, and the indurated glands showed a lessened tendency to pass on to suppuration.

Experiment O.—In the last experiment I shall quote with reference to human tuberculosis a much larger conversion of oxygen into ozone was effected.

The tubercular spleen of a guinea-pig inoculated 24 days previously with sputum was minced up in sterile beef broth filtered, diluted up to 10 C.C., and introduced into the nitrogen bulb. The mixture had a bright red colour from hæmoglobin present. A sample of the mixture was retained for control inoculation.

(Two Grove's, coil b., giving $\frac{1}{3}$-inch spark. 500 C.C. of oxygen passed per hour. Distal bulb of iodide of potassium.)

0h. 0m.—Circulation of oxygen commenced.

2h. 20m.—The first bulb is pink in colour and has a soapy opaque appearance. The K.I. solution is faintly yellow. ·0059 grm. of ozone has been passed into infusion. First sample.

4h. 20m.—Pink colour altogether gone from proximal bulb. Looks soapy and opalescent. Distal bulb, dark yellow.

5h. 30m.—Terminate experiment. Second sample. ·01373 grm. of ozone in all has been passed into the infusion, and ·001224 grm. has decomposed the iodide of potassium in the distal bulb. ·0125 grm. has therefore disappeared.

5h. 40m.—Inoculate guinea-pigs, each with three drops of the several reserved samples respectively.

Tubercle bacilli were found to be present and to stain well in the ozonised samples.

Five days after inoculation the control guinea-pig showed an enlarged gland, as large as a small lemon-seed. One of the 2h. 20m. animals showed a very slight enlargement. The rest no abnormality. In 11 days a soft glandular swelling had manifested itself in all the remaining guinea-pigs, and one is led to conclude, therefore, that the virus had not been destroyed before inoculation. I shall refer to the completion of this experiment in a subsequent report.

(*b.*) *Bovine Tuberculosis.*

Experiment P.—Material obtained from lung of guinea-pig showing abundant grey tubercles. This animal had died 50 days after inoculation. About 2 grms. of lung were reduced to a pulp, with salt solution, passed through a coarse filter, diluted up to 10 C.C., and placed in a nitrogen bulb, a control sample being reserved in a closed pipette, (Two Grove's, coil a. Slow discharge of oxygen, viz., 550 C.C. per hour. All joints air-tight.)

0h. 0m.—Commence passing oxygen.

0h. 30m.—First sample ozone.

2h. 0m.—Second sample ozone. About ·005 grm. of ozone in all generated.

Three guinea-pigs were inoculated from the samples. In 52 days the control animal died, lungs, liver, and spleen all being highly tubercular.

At this time the first ozone animal was distinctly tubercular. The second showed no glandular swelling. (In the light of other experiments I should not venture at this stage of the inquiry to attribute this immunity to the destruction of the virus.)

(In a second and very similar experiment, in which rabbits were inoculated as well as guinea-pigs, marked delay occurred in the case of the rabbit which received the most highly ozonised sample of the tubercular lung. In 27 days its inguinal gland was as large as a very small lemon-seed, whilst that of the control animal was four times the size. Very slight if any delay, however, was noticed in the case of guinea-pigs inoculated with the same samples.)

Experiment R.—A guinea-pig which had been inoculated with bovine tuberculosis 56 days previously was killed, and about 2 grms. of its lung (which was tubercular) were reduced to a pulp, with a little salt solution, filtered, diluted to 10 C.C., and placed in a nitrogen bulb.

A sample of the infusion was reserved for control inoculation. (Two Grove's, coil b, giving $\frac{1}{4}$-inch spark. Passage of 500 C.C. of oxygen per hour.)

0h. 0m.—Passage of oxygen through ozone generator and nitrogen bulbs commenced.

2h. 0m.—·006912 grm. ozone has passed. Reddish tinge persists in first bulb; only very faint yellow colour in the potassic iodide bulb. First ozone sample.

4h. 0m.—·013824 grm. ozone has passed. Red tinge disappeared, infusion looks soapy. Iodide of potassium bulb is deep brown. Second ozone sample.

6h. 0m.—·020736 grm. ozone in all has passed. Third ozone sample. ·0017 grm. of ozone passed through infusion unchanged, showing a total loss in the first bulb, during the whole experiment, of ·019036 grm.

0h. 11m.—Inoculated rabbits and guinea-pigs from the various samples.

In five days' time the control rabbit died of septicæmia; none of the other animals were indisposed at this time. (This is an interesting accident, as it seems to indicate that the micro-organism causing this disease perishes readily in presence of ozone, otherwise the remaining rabbits would probably have succumbed.) This control guinea-pig has now (18 days) a greatly enlarged and suppurating gland, whilst the third sample ozone guinea-pig shows a very faint indication of glandular enlargement. The rabbit inoculated from the first sample of ozone shows a lemon-seed sized enlargement indicative of commencing tubercular disease, but the third sample animal seems to be as yet free.

Observations.

The evidence I have obtained of the destruction of the anthrax bacillus by ozone, places my results at variance with those of Spillmann. I have incidentally remarked that after the bacilli have ceased to kill upon inoculation they still preserve an appearance so closely resembling active bacilli that it would frequently be found impossible to separate them by the microscopical appearance alone. It may be to this fact that the divergence in results is attributable, as Spillmann relied chiefly upon the microscope for the foundation of his statement. Of the experiment in which he circulated ozone through 2 C.C. of blood for seven hours it is difficult to judge as the amount of the gas generated is not quoted, and there is no sufficient evidence that spores may not have been present.

The fact that destruction of anthrax virus occurs in some cases before the cultivation (originally alkaline) assumes an acid reaction, negatives the theory that acid reaction per se was entirely causal to such destruction, although the important observations of Professor Burdon Sanderson and Mr. Laws would indicate that it would be favourable to it. The possibility of destruction or crowding-out of the anthrax bacilli owing to contamination of a given experimental solution with septic micro-organisms, is negatived by the experiments of all previous workers, who have shown that the latter rapidly perish in presence of ozone; whilst experiments of my own, which have as yet only been published in abstract, demonstrate that even in circumstances favourable to their growth none of the more ordinary species of septic bacteria could possibly effect destruction of anthrax in the time occupied by any of my experiments. We are reduced therefore to the probability of a direct action of ozone upon the protoplasm of the anthrax bacillus producing such changes as are ultimately inimical to its life or multiplication.

Disappearance of ozone in the proximal (cultivation) bulb, as estimated by its non-penetration to the distal (iodide of potassium) bulb, I found to be much more rapid at the commencement than at the end of an experiment. In all cultivations and infusions other bodies than bacilli were present which were capable of being acted upon by the ozone, and were therefore accountable to a greater or less extent for its disappearance. At the time the hæmoglobin, for instance, in an infusion containing blood, loses its colour, the absorption of ozone by the infusion

seemed to be distinctly diminished. Where it is found that large quantities (relatively speaking) of the gas are passing through the cultivation unchanged, the question might be asked whether we have not then possibly obtained a maximal effect upon the anthrax or other pathogenic microbe present. My experiments up to the present time seem rather to point to a gradation of virulency, where actual destruction of the bacillus is not attained, proceeding long after all hæmoglobin coloration has disappeared (exp. R., etc.), and I anticipate that the future course of the experiments upon human and bovine tuberculosis now under observation, will yield important evidence of this fact and will lead to the decision whether further prosecution of the investigation of the action of this gas may not be advisable.

To Dr. Russell, of St. Bartholomew's Hospital, my thanks are due for his kindness in affording me space in his laboratory for the prosecution of this work, and further for granting the use of apparatus of which I was not possessed.

No. 8.

Further Observations on Changes in Aëration of Water as indicating the Nature of the Impurities present in it; by A. Dupré, Ph.D., F.R.S.

Since my report of last year I have made a considerable number of additional experiments, which carry the research a distinct step forward. I have also applied this method of examination to the periodical testing of several of the waters supplied to London and have obtained some interesting results.

Modifications of process.

Before, however, describing these experiments, it will be well to give shortly a few alterations in the method of experimenting adopted since the last report. In the first place the bottles in which the water was to be collected (collecting bottles), as well as the bottles in which it was to be kept for the 10 days (the experimental bottles), were always sterilized by being heated from two to three hours to a temperature of from 115°—133° C. (240° to 250° F.), the neck of the collecting bottle and the open end of the tube of the experimental bottle being closed by a plug of cotton wool. Secondly, the water was always aërated by air filtered through sterilised cotton wool. Thirdly, in place of the india-rubber tubing slipped over the neck of the bottle and serving as a water joint, it was found more convenient simply to pour a little glycerine into the groove which, in nearly all bottles, is formed round the stopper by the flange round the neck of the bottles. Lastly, it was found necessary to take into consideration variations of the barometer, that is, to note the height of the barometer at the time when the water was aërated for bottling, and at the time (10 days after) when this water was compared with a sample of freshly aërated water, and to make the necessary allowance for the difference.*

The sample of water to be tested was collected in the sterilized bottle in such a manner as to avoid, as far as possible, its contact with unsterilized air. It was fully aërated by gently blowing into it by means of a small india-rubber blower a stream of air through a tube plugged with cotton wool sterilised by heat, and transferred to the experimental bottle as follows : A glass syphon tube is fixed in the neck of the bottle by means of a doubly perforated cork, one perforation carrying the syphon, the other a short glass tube plugged with cotton wool, the whole having previously been sterilized by heat. The free end of the syphon is now inserted into the neck of the experimental bottle, from which the tube has been removed and replaced by a plug of sterilized cotton wool, and the syphon is set into action by gently blowing into the collecting bottle through the plugged glass tube in the second perforation. In this way contact of the water with unsterilized air is, to a great extent, prevented. In spite of these precautions I have not, however, succeeded in bottling a water, to which gelatine had been added, in such a condition that after 10 days keeping at 20° C. (68° F.) it remained fully aërated, unless the experimental bottle, after filling as above, was again heated for some time (generally three hours) to 60° C. (see experiments 11 and 12). It should be added that the gelatine, when used, was always put into the experimental bottle just prior to this being

* The solubility of a gas at a given temperature varies directly as the pressure. If, therefore, a sample of water has been aërated and bottled at a barometric pressure of (say) 29 inches, and its aëration is compared, 10 days after, with a sample of water then freshly aërated at (say) 31 in. bar. pressure, it would appear to have lost nearly 7 per cent. even if it had, really, remained fully aërated; the apparent loss being due to the fact that the fully aërated water taken for comparison had been aërated at a higher pressure, and *vice versâ*.

filled. It was always employed in the form of a dilute solution boiled just previous to use, and always in quantity equivalent to two grains of dry gelatine per gallon of water.

Series I.—*Chelsea water boiled.*

Results of experiments.

Chelsea waters,

The first series of experiments was undertaken to test whether a water which had been sterilised by boiling could subsequently be aërated and bottled with the addition of gelatine in such a manner that it remained aërated during keeping. The water was boiled in a large flask closed by an india rubber stopper with three perforations. The first perforation carried a syphon fitted at its outer end with an india-rubber tubing and pinchcock for withdrawing the water, the second a short tube plugged with cotton wool for the escape of steam and entrance of air, and the third a long tube going to the bottom of the flask, also plugged with cotton wool. The water was kept gently boiling for about an hour, during which time small quantities of boiling water were drawn out through the syphon from time to time. The water was then allowed to cool and aërated by gently blowing air through the third tube mentioned above.*

The experimental bottle was now filled in the manner above described, the proper proportion of gelatine having been first put in, closed by its doubly bent tube stopper which was then carefully filled with the same water and placed in a water bath kept at 60° C. (140° F.) for three hours. At the end of that time the bottle was taken from the water bath, the stopper tube filled up during the cooling of the water by boiling water, glycerine poured round the stopper, and the bottle placed in the incubator kept at 20° C. (68 F.) by a Page's regulator.—Every experiment thus made (except the first two experiments of the footnote) is given in Table I., and it will be seen that in every case in which the bottle was heated, subsequent to filling, the water has remained fully aërated, all variations observed, except perhaps in the case of experiment 2, being fairly within the limits of experimental error. In the two experiments, however, in which the experimental bottle was not heated after filling, a notable diminution in the degree of aëration will be observed. The same experiment was tried repeatedly but always with the same result.

From these results we are therefore justified in concluding† that a water, if it be free from living organisms, can be bottled, with the addition of gelatine, and can be kept for ten days without diminishing in its degree of aëration, provided the experimental bottle after filling is kept for three hours at 60° C. This being established it follows that a water which under these conditions does diminish in its degree of aëration did, before the experiment was begun, contain living organisms capable of withstanding a temperature of 60° C.

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* In the first two experiments made, the water was boiled, allowed to cool, and then aërated by simple agitation, the air in the flask above the water level having of course entered during the cooling through the sterilized cotton wool, and therefore filtered. It was found, however, that even after violent agitation, the water did not become fully aërated. This was no doubt owing to the fact that the air space in the flask was, relatively to the bulk of the water, too small, and suffered a notable alteration in composition by the relatively greater abstraction of oxygen; the water was thus aërated under an insufficient pressure of oxygen.

† The reader will not need to be told that this conclusion does not affirm that all water which does, under the given conditions, maintain its aëration, is thus proved to be free from living organisms. Of course this is a different proposition.

The proviso is wanted (see bottom of previous page) on account of the risk, which I regard as inevitable, of introducing some living organisms in the course of the experiment. Organisms thus introduced are, however, in my experience always destroyed by a temperature of 60° C.

Series II.

In this series, Chelsea water, boiled or unboiled, was used, to which various proportions of sewage effluent or sewage had been added. The effluent used was produced from ordinary London sewage by the addition of 3·7 grs. of lime and 1 gr. of sulphate of iron per gallon. The sewage was ordinary London sewage clarified by simple subsidence.

Table II. gives the results obtained when sewage effluent was added to Chelsea water which had previously been boiled (sterilised). It will be seen that after such an addition the water suffered a distinct diminution in its degree of aëration even when the experimental bottle was heated to 60° C. (140° F.). When, however, the bottle was heated to 80° C. (176° F.) the water remained aërated in one of the experiments. The amount of effluent had, apparently, no influence on the degree of aëration left, but that is probably accidental. The most marked effect is noticeable when the experimental bottle was not heated after filling, in which case the degree of aëration went down to 0 °/₀ (Exp. 17). I am not inclined, however, at present to lay much stress on this result since, without heating the experimental bottle to 60° after filling, I have not yet succeeded in bottling a sterilised water, to which gelatine was subsequently added, in such a manner that it suffered no diminution in aëration during keeping, although the aëration never fell to anything near zero.

Table III. gives the results of the experiments made with sewage and unboiled Chelsea water. In this case the amount of oxygen absorbed from permanganate by the water itself, and by the same water after the addition of 30 grains of sewage per gallon, was estimated and found to be the same, viz., 0·084 grs. per gallon;—in other words the addition of this amount of sewage produced no effect on the amount of oxygen absorbed from permanganate, or at least the effect was within the limits of experimental error. The effect of only 15 grs. of sewage would therefore of course have been quite inappreciable. On the other hand, the effect of this addition on the degree of aëration was well-marked. Experiments 18, 19, 20, and 21 were made at the same time and with the same sample of Chelsea water. Experiments 22 and 23 were also made with the same water, but different from that with which the four preceding experiments had been made. These last two experiments (22 and 23) seem to me specially interesting. A comparison of experiments 19 and 21 shows that the addition of 30 grs. of sewage to the gallon lowered the degree of aëration 10 °/₀ from 83 to 73, whereas the difference in experiments 22 and 23 is no less than 35 °/₀. In the first set the water was bottled and heated to 60° C. directly after the addition of the sewage, in the second set the water by itself as well as the sample to which 15 grs. of sewage had been added, were kept for one week in the laboratory at a temperature of about 14° C. (57° F.), after which they were again fully aërated and bottled with the usual additions of gelatine. The keeping has had little or no effect on the pure water, but has greatly increased the effect of the sewage. Now as a rule a water sent for examination has not been polluted only just at the moment of its collection, but in nearly all cases pollution has gone on for some time, and in addition a day or two usually elapses between the collection of the water and its examination. The result will probably be that the effects of even an extremely trifling degree of sewage pollution will be shown in a far more marked degree than the direct experiments recorded in Table III. might lead us to expect.

Series III.

with sub-cultures of bacilli:—

Finkler's

In this series the polluting agent employed was a pure cultivation of Finkler's commabacillus cultivated in alkaline peptonised broth, for which I am indebted to the kindness of Dr. Klein, F.R.S. This is called Cultivation I. in the Table (No. IV.) The contents of the tube, which was marked Nov. 17, were a nearly clear fluid with a slight deposit at the bottom. Some of the contents were used on May 12th and May 19th. The amount given as having been added refers of course to the material as a whole, and as this was nearly perfectly clear, the actual weight of the organisms added must have been all but infinitesimal. The slight differences observed between the polluted water by itself, and the same with the addition of gelatine, is probably due to the relatively large proportion of cultivating material present, which rendered the additional amount of gelatine of little or no importance. When the amount of pollution was less, the effect of the gelatine came out more markedly. In this case also the amount (in grains per gallon) of oxygen absorbed from permanganate was estimated and found to be—

By the Chelsea water itself - - - -	0·0840
„ „ „ + 3½ grs. of Cultivation I. per gal.	0·0865

The observed increase in the amount of oxygen absorbed, small as it is, is no doubt due chiefly, if not entirely, to the cultivating material added, and not to the organisms, and the effect of the addition of only ¼-grain of this material per gallon would have been totally unnoticed. In this case also the effect of keeping the water some time after the polluting material has been added on the degree of aëration left is well-marked. (See for example Exps. 33 and 34.) In every case the water was of course fully aërated with air filtered through sterilised cotton-wool just previous to bottling.

Series IV.

bacillus subtilis.

In this series the polluting agent used was a pure cultivation of "bacillus subtilis" in alkaline peptonised broth, for which I am also indebted to the kindness of Dr. Klein, F.R.S. It is called Cultivation II. in the Table (No. V.). The tube was marked May 10, and some of the contents were used on May the 12th and 19th. The same remarks apply here as in Series III. The effect of anything above ½-gr. per gal. would be very marked. The results are given in Table V.

Observations on other London waters.

The remaining tables give the results obtained by means of the method described in this and in last year's paper with various waters supplied to London. I cannot at present profess to formulate their significance. Perhaps the most important indication, because it suggests physiological differences between one and another sort of vitalized particle contained in water, consists in the varying faculty of consuming atmospheric oxygen exhibited by waters taken at different times from the same source, the samples showing no corresponding difference in their behaviour towards other chemical tests. Thus the results of the present year obtained from the several waters are by no means identical with those of the previous year, nor do the samples taken during one month of the present year afford the same results as those taken during another month. So far as these processes furnish evidence of the presence in river waters of vitalized microscopic particles, we may perhaps deduce from this year's experiments reason for being satisfied with the filtration of the river water supplies of London. But on the other hand the results obtained with two of the deep well waters are novel, and are at present unintelligible. One of these, namely, the Trafalgar Square water, taken from a stand-pipe in New

Palace Yard, gave this year results differing widely from those obtained last year. Last year the water from this well, although it always decreased considerably in aëration when kept by itself without previous heating, yet always remained fully aërated, even after the addition of gelatine, when the experimental bottle, after filling, was heated to 60° C. In this year's experiments, heating to 60°, or in some cases even to 80° C., did not serve the same purpose. This same was found to be the case, too, with the Kent water taken from the well at Deptford (See Tables IX. and X.). Have we here other indications of differences in the life history of vitalized particles; between those present in deep well waters this year and last year; and between those present in filtered river water and in deep well waters? I propose to continue examinations of such waters at recorded periods, and for the present give simply the results obtained without attempting an explanation. [It will be noted that the results of a few later experiments confirmatory of those upon which the above report is based, are inserted while this paper is passing through the press.]

Table I.

Chelsea Water (boiled).

—	No. of Experiment.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount, in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
Simply boiled water.	1	20°	99·0	0·005	+ 2 grs. gelatine per gal., and heated after bottling to 60° C. for 3 hours.*
	2	20	96·0	0·021	„ „ „
	3	20	98·5	0·008	„ „ „
	4	20	100·0	0·000	„ „ „
	5	20	98	0·011	„ „ „
	6	20	100	0·000	„ „ „
	7	20	101†	—	„ „ „
	8	20	101	—	„ „ „
	9	20	99	0·005	„ „ „
	10	20	99	0·005	„ „ „
	11	20	64	0·194	+ 2 grs. gelatine per gal., not subsequently heated.
	12	20	78	0·118	„ „ „

Footnote to Table I.—In Experiments 7, 8, 9, 10, 11, the water was kept for 13 days in the incubator in place of the usual 10 days.

* In all experiments, where water was heated after bottling, the duration of heating was three hours.

† The apparent increase in the degree of aëration is no doubt due to experimental error.

Table II.

Boiled Chelsea Water, with addition of Sewage Effluent.

—	No. of Experiment.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount, in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
Boiled water and sewage.	13	20°	90·5	0·051	+ 2 grs. gelatine per gal. + 100 grs. effluent per gal. heated to 60° C.
	14	20	93	0·038	+ 2 grs. gelatine per gal. + 100 grs. effluent per gal. heated to 80° C.
	15	20	90·5	0·051	+ 2 grs. gelatine per gal. + 500 grs. effluent per gal. heated to 60° C.
	16	20	100	0·000	+ 2 grs. gelatine per gal. + 500 grs. effluent per gal. heated to 80° C.
	17	20	0	0·538	+ 2 grs. gelatine per gal. + 100 grs. effluent per gal. not heated.

Table III.

Chelsea Water (not boiled).

—	No. of Experiment.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount, in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
	18	20°	93	0·038	By itself, not heated.
	19	20	83	0·091	+ 2 grs. gelatine, heated to 60° C.
	20	20	89	0·059	+ 30 grains of sewage, not heated.
	21	20	73	0·145	„ „ „ + 2 grs. gelatine per gal., heated to 60° C.
	22	20	95	0·027	By itself, kept 1 week, + 2 grs. gelatine, heated to 60° C.
	23	20	60	0·215	+ 15 grs. sewage kept 1 week, + 2 grs. gelatine, heated to 60° C.

Table IV.

Chelsea Water + Cultivation I.

—	No. of Experiment.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount, in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
Boiled water.	24	20°	76	0·129	+ 3½ grs. cultivation, heated to 60° C.
	25	20	74	0·140	„ „ „ + 2 grs. gelatine, heated to 60° C.
Not boiled.	26	20	93	0·038	Chelsea water by itself, not heated.
	27	20	83	0·091	„ „ + 2 grs. gelatine, heated to 60° C.
	28	20	78	0·118	+ ½ gr. cultivation, not heated.
	29	20	71	0·156	„ „ bottled after 2 weeks keeping, not heated.
	30	20	64	0·247	„ „ + 2 grs. gelatine, heated to 60° C.
	31	20	89	0·059	+ ¼ gr. cultivation No. I., kept 2 days, not heated.
	32	20	93	0·038	+ ¼ gr. cultivation, kept 2 days, heated to 60° C.
	33	20	76	0·129	The same, + 2 gr. gelatine, heated to 60° C.
	34	20	67	0·177	+ ¼ gr. cultivation, kept 1 week, + 2 grs. gelatine, heated to 60° C.

Table V.

Chelsea Water + Cultivation II.

—	No. of Experiment.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount, in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
Boiled water.	35	20°	48	0·289	+ 3½ grs. cultivation, heated to 60° C.
	36	20	60	0·215	„ „ „ + 2 grs. gelatine, heated to 60° C.
Not boiled.	37	20	88	0·065	+ ½ gr. cultivation, heated to 60°C.
	38	20	78	0·118	+ ½ gr. cultivation, + 2 grs. gelatine, heated to 60° C.

Table VI.

Chelsea Company's Water.*

Date of Collection.	Number of Experiment.	Oxygen absorbed from Permanganate in Grains per Gallon.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at End of Experiment.	Amount in Grains per Gallon, of Oxygen consumed.	Conditions of Experiment.
January 30, 1886	39	0·1240	20°	99·5	0·003	Water by itself.
„ „ „	39*a*	—	20	99·0	0·005	„ „ heated to 60° C.
„ „ „	39*b*	—	20	96·2	0·020	+ gelatine: heated to 60° C.
February 15, „	40	0·1230	20	90·9	0·049	Water by itself.
„ „ „	40*a*	—	20	96·3	0·020	„ „ heated to 60° C.
„ „ „	40*b*	—	20	44·3	0·299	+ gelatine: heated to 60° C.
March 31, „	41	0·056	20	71	0·156	Water by itself.
„ „ „	41*a*	—	20	99	0·005	„ „ heated to 60° C.
„ „ „	41*b*	—	20	100	0·000	+ gelatine: heated to 60° C.
April 30, „	42	0·0784	20	98·3	0·009	Water by itself.
„ „ „	42*a*	—	20	99·1	0·005	„ „ heated to 60° C.
„ „ „	42*b*	—	20	96·0	0·021	+ gelatine: heated to 60° C.
May 19, „	43	0·084	20	93	0·038	Water by itself.
„ „ „	43*a*	—	20	83	0·091	+ gelatine: heated to 60° C.
June 2, „	44	0·14	20	77	0·124	Water by itself.
„ „ „	44*a*	—	20	98·5	0·008	+ gelatine: heated to 60° C.
July 30, „	45	0·051	20	81	0·102	Water by itself.
„ „ „	45*a*	—	20	94	0·032	„ „ heated to 60° C.
„ „ „	45*b*	—	20	91	0·048	+ gelatine: heated to 60° C.

* All experiments recorded in this and the succeeding tables were carried out with the unboiled water.

Table VII.

Lambeth and Vauxhall Company's Water.

Date of Collection.	Number of Experiment.	Oxygen absorbed from Permanganate.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at End of Experiment.	Amount in Grains per Gallon of Oxygen consumed.	Observations.
February 4, 1886	46	0·150	20°	95·5	0·024	Water by itself.
„ „ „	46*a*	—	20	95·9	0·022	„ „ heated to 60° C.
„ „ „	46*b*	—	20	42·2	0·311	+ gelatine heated to 60° C.
„ 23, „	47	0·085	20	102·	—	Water by itself.
„ „ „	47*a*	—	20	98·5	0·008	„ „ heated to 60° C.
„ „ „	47*b*	—	20	62·3	0·203	+ gelatine heated to 60° C.
July 15, „	48	0·069	20	96	0·022	Water by itself.
„ „ „	48*a*	—	20	94	0·032	„ „ heated to 60° C.
„ „ „	48*b*	—	20	60	0·215	+ 2 grs. gelatine „ „

Table VIII.

New River Water.

Date of Collection.	Number of Experiment.	Oxygen absorbed from Permanganate.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at end of Experiment.	Amount in Grains per Gallon of Oxygen consumed.	Observations.
February 12, 1886	49	0·113	20°	94·9	0·027	Water by itself.
„ „ „	49*a*	—	20	100·3	—	„ „ heated to 60° C.
„ „ „	49*b*	—	20	100·	—	+ gelatine heated to 60° C.
July 15, „	50	0·028	20	98	0·011	Water by itself.
„ „ „	50*a*	—	20	97	0·016	„ „ heated to 60° C.
„ „ „	50*b*	—	20	50	0·269	+ 2 grs. gelatine „ „

Table IX.

Trafalgar Square Water.

Date of Collection.	Number of Experiment.	Oxygen absorbed from Permanganate.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at End of Experiment.	Amount in Grains per Gallon of Oxygen consumed.	Observations.
February 1, 1886	51	0·0050	20°	50·	0·269	Water by itself.
,, ,, ,,	51*a*	—	20	85·5	0·078	,, ,, heated to 60° C.
,, ,, ,,	51*b*	—	20	83·9	0·087	,, ,, ,, 40° C.
,, ,, ,,	51*c*	—	20	73·5	0·142	+ gelatine heated to 50° C.
,, ,, ,,	51*d*	—	20	36·2	0·342	,, ,, ,, 40° C.
,, 12, ,,	52	—	20	58·4	0·224	Water by itself.
,, ,, ,,	52*a*	—	20	51·7	0·260	,, ,, heated to 55° C.
,, ,, ,,	52*b*	—	20	53·4	0·252	,, ,, ,, 66° C.
,, ,, ,,	52*c*	—	20	42·3	0·310	+ gelatine heated to 55° C.
,, ,, ,,	52*d*	—	20	43·8	0·302	,, ,, ,, 66° C.
,, ,, ,,	52*e*	—	20	62·0	0·204	,, ,, ,, 60° C. *
,, ,, ,,	52*f*	—	20	40·0	0·323	,, ,, ,, ,, †
March 3, ,,	53	—	20	18·	0·441	Water by itself.
,, ,, ,,	53*a*	—	20	22·	0·420	+ gelatine heated to 70° C.
,, ,, ,,	53*b*	—	20	40·	0·323	,, ,, ,, 80° C.
,, ,, ,,	53*c*	—	20	42·	0·312	,, ,, ,, ,,
June 16, ,,	54	0·014	20	42·	0·312	Water by itself.
,, ,, ,,	54*a*	—	20	60·	0·215	,, ,, heated to 60° C.
,, ,, ,,	54*b*	—	20	45·	0·296	+ gelatine heated to 60° C.

* This had been kept five days previous to bottling.
† After having been kept five days the sample was poured 12 times from one vessel to another previous to bottling in order to ensure as much contact with air as possible.

Table X.

Kent Water Company's Water.

Date of Collection,	Number of Experiment.	Oxygen absorbed from Permanganate.	Temperature of Aëration and of Incubation.	Percentage of Aëration left at End of Experiment.	Amount in Grains per Gallon of Oxygen consumed.	Observations.
February 19, 1886	55	0·0168	20°	63·5	0·196	Water by itself.
,, ,, ,,	55*a*	—	20	64·3	0·192	,, ,, heated to 60° C.
,, ,, ,,	55*b*	—	20	73·4	0·143	+ gelatine heated to 60° C.
March 9, ,,	56	—	20	49·	0·274	Water by itself.
,, ,, ,,	56*a*	—	20	34·	0·355	+ gelatine heated to 70° C.
,, ,, ,,	56*b*	—	20	50·	0·269	,, ,, ,, 80° C.
,, ,, ,,	56*c*	—	20	44·	0·301	,, ,, ,, ,,
July 14, ,,	57	0·018	20	58·	0·226	Water by itself.
,, ,, ,,	57*a*	—	20	66·	0·183	,, ,, heated to 60° C.
,, ,, ,,	57*b*	—	20	33·	0·360	+ 2 grs. gelatine ,, ,,

APPENDIX C.

App. C. No. 1.
Memorandum by Dr. Bridges.

Memorandum by Dr. J. H. Bridges on Small-Pox Hospitals of Metropolitan Asylums Board.

The President, January 10, 1887.

I submit, in accordance with your request, a few remarks as to the small-pox hospital question; so far as my own experience in connection with the hospitals of the Metropolitan Asylums Board may qualify me to express an opinion on the subject.

There are two distinct questions which it is essential to keep apart, though in practice they are often mixed up together:

1. Do small-pox hospitals spread disease around them?
2. Is infection carried for long distances through the atmosphere, or is it conveyed only through very short distances, and propagated by human communication?

To the first question I have to answer that the experience of the last fifteen years in the metropolis is to the effect that the establishment of small-pox hospitals has been in those cases where it has been closely examined followed by an appreciable increase of the disease in the immediate neighbourhood of the hospital. Observers were slow to form this conclusion, because a long time passed before any adequate examination of the fact was made. A great mass of statistics was required, not merely as to the amount of small-pox in a special region, but as to the precise population of that region. To reach a distinct conclusion, in which other obvious cases of small-pox contagion could be eliminated, it was necessary to wait till the evidence of successive epidemics had accumulated. My report on Homerton of January 1881 was the occasion for instituting the more systematic and elaborate inquiry carried on through two successive epidemics by Mr. Power. The facts so laboriously collected by him, and arranged with such masterly lucidity, show clearly that a small-pox hospital in a populated neighbourhood has been, with all the precautions as yet devised, an appreciable source of danger to that neighbourhood.

The charts laid by the Metropolitan Asylums Board before the Royal Commission of 1882 went to the same conclusion. These charts offered one great advantage, as compared with the data of any previous inquiry. They exhibited the diffusion of small-pox throughout the whole area of the Metropolis. And they went to establish this very important practical conclusion, more distinctly formulated by the Registrar-General in the Annual Summary of 1881 and that of 1884, that "it must not be supposed for a moment that on an occasion of disease "the presence of a hospital bears any sort of comparison with the "other deleterious influences from which London suffers." *See* Report, Commission, p. xxiii.

The Registrar-General, in his annual summary of births, deaths, and causes of death in London for 1881, observes, p. viii.:—

"It may possibly be the case that, though within the limits of a given group of districts, that district which contains the small-pox hospital may be the one which derives, on the whole, least benefit from it, or rather which has the benefit conferred by it counterbalanced by some small disadvantage, yet that the absence of a hospital altogether from a group of districts, may be a still greater evil, by leading to a comparative inability or disinclination to make use of a hospital situated

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at a distance . . . . . A comparison of the different groups of districts with each other in respect of the degree in which they severally avail themselves of the public hospitals confirms this view. The group with the *lowest* small-pox death-rate is the one which contains no hospital, but sends the largest proportion of its cases to hospitals outside its limits. The group with the *highest* small-pox death-rate is that which has no hospital within its limits, and makes less use than any other of the hospitals outside its limits. The other groups are intermediate to these."

In the annual summary of deaths of 1884 the conclusion derived from the facts of another epidemic is similar; viz., that—

"Those districts are worse off which neither have hospitals of their own nor make use of the hospital outside, while those districts are best off which have no hospitals within their own areas, but make full use of hospitals outside their borders; while intermediate is the condition of those districts which have hospitals within their limits and make use of them." p. vii.

I come now to the second question: Is there in the data, supplied by Mr. Power in his reports of 1881, 1884, and 1885, any proof that infection is carried atmospherically through long distances?

The question is discussed at some length by the Commission of 1882 in the 11th section of their report, pp. xxii.–xxvii. They discuss the evidence on either side and leave the question undecided.

Does the evidence since adduced by Mr. Power decide the point. I have re-read his three reports with a sincere attempt to disengage myself from the natural bias in favour of opinions previously expressed. But I am quite unable to find anything that seems to me to approach to scientific proof of the view held by Dr. Buchanan, viz., that small-pox tends to spread from a hospital containing five beds, independently of lines of human communication.

Of the immense series of facts collected by Mr. Power in his three reports two only appear to have a definite bearing on this part of the subjects:—

1. In the five days, January 26–30, 1881, an attack of 32 cases occurred in the "special area" of a mile radius round the Fulham Hospital. These cases were presumably infected in the days January 13–17. In 23 of these 32 cases the source of infection remained, after careful inquiry, unaccounted for. The admission of acute cases into the Fulham Hospital began five days previous to the date at which these persons were infected, *i.e.*, January 8.

2. In the seven days May 31—June 6, 1884, an outbreak of 24 cases occurred in the same special area. [In how many of these cases the origin of the disease could be accounted for by ordinary causes is not stated.] These cases were presumably infected between May 19—25. The admission of acute small-pox cases into Fulham had begun on May 15; and between May 19—25 there were from five to eight patients in the hospital.

These two sets of facts are the only two in Mr. Power's very detailed reports which bear on the special question of what I call distal contagion, as opposed to contagion at short distances by the ordinarily recognised modes. The subsequent history of the epidemic around Fulham in 1881 or 1884 hardly bears on the question, because these few cases, once established, would communicate contagion to others in the ordinary way. As Professor Burdon Sanderson observed in his questions to Dr. Dudfield (*see* specially Qu. 4751, p. 265, and Qu. 4818, p. 268, of Report of Royal Commission), "No one suggests that the

" spread of small-pox after an outbreak has commenced is due to atmo-
" spheric influence; the important point is the commencement of the
" outbreak." Mr. Power's very important note on p. 306 of his report of 1881 is to the same effect.

Now these two sets of facts, the outbreak of January 26–30, 1881, and of May 31—June 6, 1884, seem to me to form a very slender basis for the inference that small-pox infection can be conveyed a mile through the atmosphere, independently of human communication.

In disputing the validity of this inference, I remark—

1. During each of the invasion periods (dating these 13 days before the outbreak) there were a large number of outgoings of officers from the hospital, and of incoming persons, whether as tradesmen or visitors. These outgoings and incomings in the six days of January 12–17, 1881, were 439, and during May 19–23, 1884, were 187 ; so that on neither occasion were means of propagation by the ordinary modes absent.

2. What happens at any period in the special area round Fulham Hospital must be taken in connexion with what is taking place in the whole metropolitan area. Now the two sudden outbreaks of January 1881 and of May 1884 appear to me merely parts, specimens as it were, of a general rise simultaneously, or nearly simultaneously, taking place at those periods throughout the metropolis.

Thus, the admissions from the whole metropolitan area were for fortnight ending—

December 25, 1880	-	-	152
January 8, 1881	-	-	219
January 22, „	-	-	227
February 5, „	-	-	325

The last fortnight, including the special outbreak which drew Mr. Power's attention shows an increase of 43 per cent. over fortnight preceding.

In the second of Mr. Power's special periods, that beginning May 31, 1884, there is not quite the same correspondence. But a striking and very notable rise had taken place in the admissions to the metropolitan hospitals very shortly before this comparatively small Fulham outbreak; *e.g.*, the admission in the five days May 24–28 had been 339, as against 143 in the five days previous. The reason of this and similar sudden oscillations in the course of an epidemic are, I suppose, as little known to us as that of the periodicity with which every three or four years small-pox epidemics tend to recur.

3. Much stress has been laid upon the fact that the two outbreaks of January 1881 and June 1884, did not appear to follow in any marked way the principal lines of traffic. I am not sure whether on any theory of small-pox communication they could be expected to follow those lines. In those cases, for instance, where ambulances stopping on their journey have been in former years a medium of dissemination (or possibly, may even now disseminate it when all such stoppages are prevented), the persons injured though they might be infected in the high street, yet would for the most part live in side streets, and the cases would appear in side streets on a small-pox map. The same remarks would apply to other modes of communication by nurses or tradespeople.

4. There appear to be some rather striking exceptions in Mr. Power's second report to his rule of uniform dissemination round the hospital as a focus, with increasing intensity as the focus is approached. For instance, on the diagram facing page 78 of the 1884 Report, showing the circular

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area round the hospital divided into quadrants, I note that the 121 houses within a quarter of a mile of the hospital on the north-west aspect did not present a single case of small-pox during the whole period from the 25th May to the middle of September 1884. During this period, in which 153 admissions had taken place into the hospital, only three cases of small-pox had occurred in the quarter-mile circle. This could not have been due to the fact that the susceptibility of the population had been exhausted, because in this same circle, and in the north-west quadrant of it, numerous cases did occur at a later period, due, as I suggest, to direct contagion, either from cases in regions more remote from the hospital, or from communication with the hospital servants or tradesmen. In any case the immunity of these 121 houses during a period of between three and four months is a fact militating, I think, against the theory of atmospheric contagion. Again, I note that during the six weeks from the 3rd of August to the 13th of September, whereas nine cases occurred outside the special area in the three parishes, only one occurred within that area. See Table A., page 118, of Report of 1885. These facts show, I think, that if atmospheric dissemination operate at all, it operates very uncertainly and capriciously.

5. Mr. Power, however, admits this irregularity, and has admitted it from the first. He has always laid stress on the meteorological conditions which, in his opinion, favour dissemination. In his Report of 1881 (pp. 329–332), he dwells on the exceptional conditions of the atmosphere during the five days, January 13–17, when he supposes dissemination to have taken place: especially on the fact of still, foggy weather, under a cloudless sky, with light variable winds.

On page 80 of the Report of 1884, he institutes a comparison between the weather of January 13–17, 1881, and that of May 19–23, 1884, calling attention to their striking similarity. On referring to the actual weather records of those days the similarity does not seem to me quite so striking. The fog of 1881 was dense ; that of 1884 slight. Two days in the 1884 period were by no means cloudless. Finally, the air in the five days of 1884, travelled 912 miles as against 707 miles in the five days of 1881. There are other differences on which, however, I do not dwell, because it would appear from the remarks on pages 77 and 81 of his Report of 1884 that Mr. Power himself doubts how far any definite set of meteorological conditions support the theory of atmospheric dissemination.

6. It is evident that the proof that so small a number as five cases of acute small-pox assembled in a hospital ward can disseminate small-pox at a mile distance is attended by special difficulties. If five cases can do it, why not two or three? And if two or three, then, since there are many such small collections in all epidemics in private houses, there arises the difficulty of distinguishing their influence from that of the hospital.

It would seem to me that a necessary condition for scientific proof of atmospheric dissemination of contagion through a circle of a mile radius, would be the elimination of all means of ordinary communication in the intervening space. This would imply the necessity of choosing for observations the neighbourhood of an hospital situate a mile away from inhabited houses, and where adequate care was taken to keep the inhabitants from contact with the hospital, or with other sources of contagion. Certain facts brought by Dr. Collie and myself before the Royal Commission appeared to indicate that, where a really secluded population, like the population of a workhouse or prison, was brought into very close contiguity to a small-pox hospital, no infection followed, even

though no special precaution had been taken to protect that population by re-vaccination. I do not think that quite sufficient weight has been attached to these facts by those who regard the theory of atmospheric contagion at long distances as proved.

With regard to the practical steps recommended in the case of the Metropolitan Asylums Board Hospitals, I have addressed a further memorandum to the Board.

J. H. B.

10th January 1887.

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